Merle Streitberger, Werner Ackermann, Thomas Fartmann, Giulia Kriegel, Anne Ruff, Sandra Balzer und Stefan Nehring

Eckpunkte eines Handlungskonzepts für den Artenschutz in Deutschland unter Klimawandel

Key points for an action plan for species conservation under climate change in Germany
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Key points for an action plan for species conservation under climate change in Germany

Zusammenfassung der Ergebnisse aus dem F+E-Vorhaben „Strategien und Handlungskonzept für den Artenschutz in Deutschland unter Klimawandel“ (FKZ 3513 86 0800) /

Summary of the Research and Development Project (FKZ 3513 86 0800)

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**Titelbild / Cover:** oben links / above left: Berg-Mähwiese im Hochsauerland / Montane meadow in Central Germany (Hochsauerland); oben rechts / above right: Langer Landschaftsgradient in der Prignitz / Long landscape gradient (Prignitz, Northeast Germany); unten links / below left: Goldener Scheckenfalter / Marsh fritillary (Euphydryas aurinia); unten rechts / below right: Europäischer Frauenschuh / Lady’s-slipper orchid (Cypripedium calceolus) (Fotos / Photos: alle / all ©Thomas Fartmann)

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Durch die Verringerung des Sommerniederschlags steigt das Austrocknungsrisiko für kleinere Stillgewässer.

The risk of drying up increases for small water bodies due to the reduction of summer rainfalls.

(Foto / Photo: Thomas Fartmann)
Vorwort

In den letzten Jahrzehnten hat das wissenschaftliche und naturschutzpolitische Interesse an der Bedeutung des anthropogen verursachten Klimawandels für die Gefährdung und das Aussterben von Arten deutlich zugenommen. Durch die zum Teil unaufhaltsamen Folgen des Klimawandels besteht nicht nur ein hoher Bedarf, Anpassungsmaßnahmen seitens des Naturschutzes zu entwickeln und mit jenen anderer Politikbereiche abzugleichen, sondern auch Zielsetzungen neu zu definieren.

Um für den Artenschutz eine fundierte fachliche Basis zu schaffen, hat das BfN das Forschungs- und Entwicklungsvorhaben (F+E) „Strategien und Handlungskonzept für den Artenschutz in Deutschland unter Klimawandel“ initiiert. Der vorliegende Band stellt im Ergebnis Eckpunkte für ein zukunftsfähiges Handlungskonzept vor. Um die wichtigen Ergebnisse auch international verfügbar zu machen, wurden die Eckpunkte zusätzlich ins Englische übersetzt.

Das Gesamtgutachten des F+E-Vorhabens ist ebenfalls publiziert:


Das Vorhaben führte die relevanten Erkenntnisse der in den letzten 10 Jahren durch das BfN durchgeführten Ufoplan-Vorhaben zusammen, die sich mit den direkten und indirekten Auswirkungen des Klimawandels auf Arten und Naturschutz beschäftigten. Ergänzt wurde die Synthese durch eine umfassende Literaturrecherche zum Thema.

Es ist seit längerem Konsens, dass erhebliche Anstrengungen notwendig sind, um einzelne Lebensgemeinschaften angesichts der durch den Klimawandel zu erwartenden Veränderungen in der gegenwärtigen Form zu erhalten. Das Vorhaben formuliert für den Naturschutz die grundsätzliche Anforderung, die Ziele des Artenschutzes im Hinblick auf den Klimawandel zu überprüfen und zu konkretisieren. Es werden voraussichtlich Anpassungen und veränderte Schwerpunktsetzungen notwendig werden. Auch wenn die Erhaltung der aktuell natürlicherweise vorkommenden Arten als zentrales Ziel weiter verfolgt wird, müssen Handlungsoptionen zur Erreichung dieses Oberziels dynamisiert werden. Im Vordergrund sollte vor allem die Erhöhung der Anpassungskapazität von Biotopen und Arten durch die Erhaltung ökosystemtypischer Funktionen und Eigenschaften stehen.

Große Kenntnislücken und damit Forschungsbedarf in Bezug auf den direkten Einfluss des Klimawandels bestehen vor allem für viele gefährdete bzw. seltene Arten sowie insbesondere für Quellen, Feuchtheiden, Küstenhabitate und marine Lebensräume.

Wir hoffen, dass die vorliegende Studie mit Informationen und Empfehlungen in den nächsten Jahren einen wichtigen Beitrag bei der Diskussion, Abwägung und Implementierung eines zukunftsfähigen Handlungskonzeptes für den Artenschutz unter Klimawandel leisten wird.

Prof. Dr. Beate Jessel
Präsidentin des Bundesamtes für Naturschutz
As a result of global warming southerly distributed species like the European Praying Mantis (\textit{Mantis religiosa}) increasingly expand their range in Central Europe.

(Foto / Photo: Thomas Fartmann)
Eckpunkte eines Handlungskonzepts für den Artenschutz in Deutschland unter Klimawandel

1 Einleitung

1.1 Klimawandel in Deutschland


1.2 Auswirkungen des Klimawandels auf die Biodiversität


In Folge des Klimawandels wirken sich vor allem die folgenden Faktoren auf die Biodiversität aus und bewirken Veränderungen innerhalb von Lebensgemeinschaften (ESSL & RABITSCH 2013, MOSBRUGGER et al. 2014, PETERMANN et al. 2007, RABITSCH et al. 2010):

- physiologische Änderungen (z.B. durch Beeinflussung des Stoffwechsels, der Reproduktion oder der Mortalität) und Verhaltensänderungen von Arten,
- phänologische Änderungen,
- Veränderung biotischer Interaktionen (z.B. durch phänologische oder räumliche Entkopplungen von Interaktionspartnern),
- Arealverschiebungen (Veränderungen von Artengemeinschaften, Aussterben von Arten),
- Lebensraumveränderungen durch klimatische Änderungen.


1.3 Ziele des Vorhabens

Aufgrund der weitreichenden Folgen des rezenten Klimawandels für die Biodiversität wurde durch das Bundesamt für Naturschutz (BfN) eine ganze Reihe von Ufoplan-Vorhaben durchgeführt, um die direkten und indirekten Auswirkungen des Klimawandels auf Arten und Lebensräume zu identifizieren und Handlungsempfehlungen für den Naturschutz abzuleiten.

Für weite Teile Mitteleuropas wird ein Rückgang der Großen Moosjungfer (*Leucorrhinia pectoralis*) prognostiziert.

For wide parts of Central Europe a decline of the Yellow-spotted Whiteface (*Leucorrhinia pectoralis*) is predicted.

(Foto / Photo: Thomas Fartmann)
2 Methoden zur Erarbeitung des Handlungskonzeptes


Historische Waldnutzungsformen wie die Mittelwaldbewirtschaftung fördern lichtliebende Waldarten.

Traditional forms of woodland management such as coppicing promote woodland species dependent on light forest structures.

(Foto / Photo: Thomas Fartmann)
3 Ergebnisse: Handlungskonzept

3.1 Meere und Küsten

Direkte und indirekte Auswirkungen des Klimawandels


Handlungserfordernisse und Anforderungen an Sektoren


Um die Gefährdungsdisposition für marine Fischarten zu reduzieren, ist die konsequente Umsetzung einer ökologisch verträglichen Fischerei dringend notwendig. Die Fischerei muss sich in Bezug auf die Fangmengen (inkl. des Beifangs) daran orientieren, dass ausreichend große Fischbestände erhalten bleiben. Für die Europäische Union fordert inzwischen auch die Gemeinsame Fischereipolitik (CFP 2014) die Erholung der Bestände in einem angemessenen Zeitrahmen über diejenigen Bestandsgröße hinaus, die einen maximalen nachhaltigen Ertrag gewährleisten kann. Gleichzeitig müssen die negativen Auswirkungen der Meeresfischerei auf andere Komponenten mariner Ökosysteme minimiert werden. Insbesondere der Einsatz von aktiven, grundberührenden Fanggeräten sollte kontinuierlich verringert werden. In Schutzgebieten sollten diese Fangmethoden gänzlich untersagt werden.

Regelwerke (s. OJAVEER et al. 2014) durch die betroffenen Sektoren (v.a. Schifffahrt, Aquakultur).

Zur Umsetzung der Handlungserfordernisse ergeben sich daher die folgenden Anforderungen an die betroffenen Sektoren:

- **Fischerei/Schifffahrt:** Umsetzung einer nachhaltigen Fischerei (v.a. angepasste Fangquoten gem. CFP [2014]; Schonung des Meeresbodens zumindest in Schutzgebieten; Entwicklung ökologisch verträglicher Fangmethoden) und Berücksichtigung von Maßnahmen zur Vermeidung der Verschleppung gebietsfremder Arten (v.a. Berücksichtigung von Ballastwasser-Regelungen; Müllvermeidung und die Entwicklung ökologisch verträglicher Schiffsanstriche, s. OJAVEER et al. 2014)

- **Aquakultur:** Verzicht auf die Kultivierung invasiver Arten; Berücksichtigung entsprechender Richtlinien zum Umgang mit gebietsfremden Arten (s. OJAVEER et al. 2014),

- **Politik:** verstärkte Ausrichtung der Fischereipolitik an ökologischen Gesichtspunkten und konsequente Anwendung von Überwachungsmaßnahmen; schärfere Regulierung zur Vermeidung von Plastikmüll aus der Fischerei und Schifffahrt (s. INTERNATIONAL CONFERENCE ON PREVENTION AND MANAGEMENT OF MARINE LITTER IN EUROPEAN SEAS [2013]) und des Einschleppens gebietsfremder Arten; schärfere gesetzliche Regelung zur verpflichtenden Umsetzung von Artenschutzmaßnahmen im Zuge des Ausbaus von Offshore-Windenergieanlagen,

- **Raum- und Landschaftsplanung/Küstenschutz:** stärkere Berücksichtigung erforderlicher Anpassungsmaßnahmen des Naturschutzes (z.B. Ausbau des Biotopverbundsystems, v.a. Deichöffnung und Deichrückbau) bei der Ausgestaltung von Raum- bzw. Landschaftsplänen,

- **Energiewirtschaft:** Berücksichtigung von Artenschutzmaßnahmen beim Ausbau von Windkraftanlagen (z.B. Schallschutzmaßnahmen bei Rammarbeiten); Weiterentwicklung von Schutzmaßnahmen unter der Berücksichtigung neuester wissenschaftlicher Erkenntnisse.

**Forschungsbedarf**

Um die langfristigen Auswirkungen des Klimawandels auf marine Arten, Arten zu identifizieren, die besonders vom Klimawandel betroffen sind (z.B. durch Empfindlichkeitsanalysen) und als Indikatorarten dienen können. Dabei ist es vor allem erforderlich, die Anpassungskapazität mariner Arten an die veränderten Umweltbedingungen verstärkt zu untersuchen, um die Auswirkungen auf Arten, Arten, Arten besser verstehen zu können. Noch weitgehend unerforscht sind die interaktiven Wirkungen unterschiedlicher klimawandelbedingter Effekte auf Ökosysteme und Arten (z.B. Erwärmung und Versauerung, s. PORTNER 2006).

Um nachhaltige Schutzmaßnahmen zur Erhaltung von Küstenhabitaten durch Deichöffnung oder -rückbau aus planerischer und gesellschaftlicher Sicht durchsetzen zu können, besteht Forschungsbedarf zur Entwicklung von rechtlichen und planerischen Lösungen. Des Weiteren muss verstärkt untersucht werden, wie sich Sandanreicherungsmaßnahmen auf ökologischer und küstenmorphologischer Ebene auswirken (CPSL 2010).

sich ausbreitende gebietsfremde Arten besteht dringender Bedarf, den Kenntnisstand zur Ausbreitung speziell invasiver Arten zu vertiefen und die sich daraus ergebenen Auswirkungen auf marine Lebensräume und Küstenökosysteme zu analysieren (KATSANEVAKIS et al. 2014, OJAVEER et al. 2014). Dabei ist es vor allem erforderlich, die Überlebens- und Ausbreitungsstrategien invasiver Arten, die Einflüsse des Menschen auf die Ausbreitung invasiver Arten und die Verbreitung gebietsfremder Arten auf kontinentaler Ebene zu analysieren. Dies gilt vor allem für unzureichend untersuchte Taxa (v.a. einzellige Organismen, Mikroorganismen allg.).

3.2 Fließgewässer und Quellen

Direkte und indirekte Auswirkungen des Klimawandels


Entsprechend den Ausbaubeziehen des Bundes zu erneuerbaren Energien ist grundsätzlich eine Zunahme der Wasserkraftnutzung zu erwarten. Werden Maßnahmen zur Erhaltung der Gewässerdurchgängigkeit nicht im ausreichenden Maße berücksichtigt, ist mit dramatischen Auswirkungen für die Artenvielfalt in Fließgewässern zu rechnen. Bei zunehmenden Niedrigwasserperioden steigt zusätzlich der Bedarf, bestehende Anlagen an die veränderten Abflussverhältnisse baulich anzupassen, um die abflussbedingten Mindererzeugungen zu kompensieren (WOLF-SCHUMANN & DUMONT 2010). Die ökologischen Folgen sind aufgrund der unsicheren Prognosen noch nicht abzuschätzen. In Folge einer Zunahme der Querverbau-
ungen an Fließgewässern erhöht sich das Gefährdungsrisiko vor allem für wandernde Gewässerorganismen. Durch die sich daraus ergebende räumliche Einschränkung sind Anpassungsmaßnahmen in Form von Ausweichbewegungen für Gewässerorganismen nur begrenzt möglich.

**Handlungserfordernisse und Anforderungen an betroffene Sektoren**

Zum Schutz hoch gefährdeter Arten der Fließgewässer und Quellen und Minimierung negativer Auswirkungen des Klimawandels ergeben sich die folgenden Handlungserfordernisse:

- **Erhaltung naturnaher Fließgewässer und Quellen:** Verzicht auf einen Ausbau von naturnahen Fließgewässern und auf eine weitere Errichtung von Wasserkraftwerken sowie auf Maßnahmen, die zu einer Veränderung des Wasserregimes von Quellen führen,

- **Renaturierung von Fließgewässern und Auen:** Wiederherstellung naturnaher Strukturen und dynamischer Prozesse innerhalb von Auen und Fließgewässern zur Erhöhung der Resilienz der Ökosysteme gegenüber veränderten Umweltbedingungen und Schaffung naturnaher Lebensräume,

- **Förderung positiver Synergieeffekte zwischen Natur- und Hochwasserschutz:** Schaffung dauerhafter Überschwemmungsflächen durch entsprechende Maßnahmen (z.B. Deichrückbau) zur Verbesserung der Ökosystemfunktion von Auen (Hochwasserretention, Nährstoffretention, Habitatfunktion, Kohlenstoffvorrat, s. SCHOLZ et al. 2012),

- **Verbesserung der Gewässerqualität (durch Pufferzonen, landwirtschaftliche Extensivierung):** Reduzierung von Stressfaktoren durch anderweitige Gefährdungen (v.a. Eutrophierung) zur Förderung von durch den Klimawandel gefährdete Arten (v.a. kaltstenotherme Arten, DOMISCH et al. 2011),

- **Reduktion der Einleitung von Kühlwasser:** v.a. in Phasen mit extremen Sommertemperaturen sowie Niedrigwasser,

- **Maßnahmen zur Verhinderung der Austrocknung von Quellen:** Steigerung der Grundwasserneubildung und Erhöhung der Quellschüttung durch entsprechende Maßnahmen (z.B. Maßnahmen zur Regenwasserversickerung z.B. über Sickerpfaster oder Muldenversickerung, s. PODRAZA 2012).

Zur Umsetzung der Handlungserfordernisse ergeben sich die folgenden Anforderungen an die betroffenen Sektoren:

- **Wasserwirtschaft/Energiewirtschaft:** Verzicht auf einen weiteren Gewässerausbau und Errichtung von Kraftwerken; Renaturierung von Fließgewässern und Auen unter der Berücksichtigung von Synergieeffekten zwischen Hochwasser- und Naturschutz; Ausbau bestehender Wasserkraftanlagen unter Berücksichtigung erforderlicher Maßnahmen zur Erhaltung der Durchgängigkeit; Reduzierung der thermischen Belastung von Fließgewässern durch Investitionen in Kühltürme (BÖLSCHER et al. 2013),

- **Landwirtschaft:** Einrichtung und Einhaltung von Pufferstreifen zu angrenzenden Gewässern,

- **Fischerei:** Verzicht auf den Fang gefährdeter Arten und auf einen Besatz mit gebietsfremden Arten,

- **Raum-/Landschaftsplanung:** Verringerung der Flächenversiegelung zur Erhöhung der Grundwasserneubildungsraten; Ausweisung von Hochwasserretentionsräumen als Hochwasserschutz- und Renaturierungsflächen.

**Forschungsbedarf**

Zwar stand in den letzten Jahren die Erforschung der Auswirkungen des Klimawandels auf Fließgewässer zunehmend im Fokus der Gewässerökologie. Jedoch sind noch viele Zu-
sammenhänge unklar, was nicht zuletzt auf der hohen Komplexität der Fließgewässerökosysteme beruht. Aus Sicht des Artenschutzes ist die weitergehende Erforschung der folgenden Aspekte besonders erforderlich, um konkrete Anpassungsmaßnahmen an den Klimawandel abzuleiten:

- Reaktion der Quellfauna auf den Klimawandel,
- Einfluss einer zunehmenden Isolierung kalt-stenothermer Organismen auf die genetische Vielfalt,
- Ausbreitung von gebietsfremden Arten durch den Klimawandel und Auswirkungen auf Lebensgemeinschaften,
- Verbesserung des Kenntnisstandes zum ökologischen Zustand von Auen zur Ableitung entsprechender Renaturierungsmaßnahmen (s. SCHOLZ et al. 2012),
- Verhalten von Wanderfischarten beim Fischabstieg an Wasserkraftanlagen.

3.3 Stillgewässer

Direkte und indirekte Auswirkungen des Klimawandels


Indirekt sind Stillgewässer vor allem durch die intensivierte Landnutzung gefährdet, die unter anderem mit dem erhöhten Flächenanspruch zur Gewinnung von Energiepflanzen zusammenhängt und erhöhte Nährstoffeinträge in Gewässersysteme bewirkt. Durch die landwirtschaftliche Intensivierung sowie zunehmende sommerliche Trockenperioden steigt zusätzlich der Wasserbedarf zur Bewässerung landwirtschaftlicher Systeme, was ein weiteres Gefährdungsrisiko für Gewässerökosysteme darstellt (HAASE et al. 2012, SCHÄDLER 2002).

Handlungserfordernisse und Anforderungen an betroffene Sektoren

Zum Schutz und zur Förderung der Artenvielfalt und gefährdeter Arten in Stillgewässern ergeben sich im Zuge des Klimawandels die nachfolgend beschriebenen Handlungserfordernisse und Anforderungen an betroffene Sektoren. Die Handlungserfordernisse beinhalten vor allem Maßnahmen, die die Gefährdungsbelastung reduzieren und eine höhere Anpassung des Lebensraumes bzw. der Arten an veränderte Umweltbedingungen ermöglichen:

- Verbesserung der Wasserqualität: Minimierung von Nährstoffeinträgen durch Extensivierung der landwirtschaftlichen Nutzung und Anlage von Pufferstreifen; Maßnahmen zur Verringerung von Nährstoffeinträgen durch Zuflüsse (NLWKN 2011),
- Entschlammung, Entkrautung und Oberbodenabtrag im Uferbereich: Reduzierung der Nährstoffbelastung eutrophierter Gewässer,
- Sicherung und Optimierung eines lebensraumtypischen Wasserhaushaltes: Wasserstandsregulierung innerhalb künstlicher und ausgebauter Seen zur Kompensation von durch den Klimawandel verursachten Wasserspiegelabsenkungen,
- Optimierung der Gewässerstruktur: Erhöhung der Struktur- bzw. Habitatvielfalt im Gewässer und am Ufer zur Ermöglichung von Ausweichbewegungen,


Forschungsbedarf

Für den Artenschutz bedeutsam sind außerdem tiefergehende Untersuchungen, inwieweit Gewässerorganismen auf den gesunkenen Sauerstoffgehalt im Hypolimnion reagieren und durch spezifische Reaktionsmechanismen Veränderungen innerhalb von Lebensgemeinschaften hervorrufen werden.


Ähnliches gilt auch für die Ausbreitung gebietsfremder Arten. Um negative Auswirkungen auf gefährdete Arten frühzeitig erkennen und entsprechend handeln zu können, ist es dringend erforderlich, die Ausbreitung von gebietsfremden Arten verstärkt unter dem Aspekt des Klimawandels zu untersuchen.

3.4 Felsen, Block- und Schutthalden, Geröllfelder sowie Rohbodenhabitate

Direkte und indirekte Auswirkungen des Klimawandels


Innerhalb feuchter Rohbodenhabitate in Auen oder an Gewässerufern sind vor allem hygrophile Arten durch die zunehmende Austrocknung bedroht. Ähnliches gilt auch für Arten, die an Kleingewässer gebunden sind und innerhalb rohobdenreicher Habitatkomplexe wie etwa Steinbrüchen vorkommen (z.B. Gelbauchunke Bombina variegata, Knoblauchkröte Pelobates fuscus, s. BEHRENS et al. 2009a, DITTRICH & RÖDEL 2014).

Hinweise auf ein Gefährdungsrisiko durch indirekte Auswirkungen des Klimawandels liegen für Arten fels- oder gesteinsreicher Lebensräume bislang nicht vor. Durch den zunehmenden Ausbau erneuerbarer Energien und den damit einhergehenden erhöhten Flächenbedarf besteht ein potenzielles Gefährdungsrisiko, wenn Lebensräume in Folge des erhöhten Nut-
zungsdrucks zunehmend in eine nicht-artenschutzkonforme Nutzung überführt bzw. beeinträchtigt werden (z.B. durch Nährstoffeinträge in Folge der intensivierten Landnutzung).

**Handlungserfordernisse und Anforderungen an betroffene Sektoren**


Zur Umsetzung der Handlungserfordernisse ergeben sich die folgenden Anforderungen an die entsprechenden Sektoren:

- Raum-/Landschaftsplanung: Umsetzung der erforderlichen Schutzmaßnahmen (Ausweisung von Schutzgebieten; Aufbau von Biotopverbundsystemen auf lokaler und landesweiter Ebene; naturnahe Rekultivierung, Maßnahmen zur Lenkung des Kletter- und Wandersports, Verzicht auf Gesteinsabbau; Verzicht auf Aufforstungen bzw. Nutzungsänderung),
- Forstwirtschaft: Verzicht auf eine intensive forstliche Nutzung im Umfeld bewaldeter Blockhalden bzw. Felsbiotope,
- Klettersport: Berücksichtigung von Betretungsverboten.

**Forschungsbedarf**

Ein langfristiges Monitoring der Entwicklung der Habitat e bzw. charakteristischer Indikatorarten (z.B. kalt-stenotherme Arten, Glazialrelikte innerhalb von Blockhalden) ist notwendig, um die Auswirkungen des Klimawandels auf gefährdete Arten bzw. Artengemeinschaften besser verstehen zu können. Ein dringender Bedarf für ein Monitoring besteht vor allem für die Lebensgemeinschaften der Blockhalden mit Kaltluftautritt en. Für die jeweiligen Offenhabitate müssen entsprechend geeignete Indikatorarten bzw. -artengruppen identifiziert werden, die
in ein langfristiges Monitoring eingebunden werden sollen. Aufbauend auf den Erkenntnissen müssen konkrete Schutzmaßnahmen für die gefährdeten Arten bzw. Lebensgemeinschaften abgeleitet werden.

3.5 Äcker und Ackerbrachen

Indirekte Auswirkungen des Klimawandels


Handlungserfordernisse und Anforderungen an betroffene Sektoren

Die Berücksichtigung von Maßnahmen zur Erhaltung und Erhöhung der Habitatvielfalt in der Agrarlandschaft ist im Zuge des zunehmenden Energiepflanzenanbaus bzw. der allgemeinen landwirtschaftlichen Intensivierung von besonderer Bedeutung für die Erhaltung der Agrarbiodiversität. Die folgenden Handlungserfordernisse sind dabei besonders relevant:

- Verzicht auf Nutzungsintensivierung und Berücksichtigung von Artenschutzmaßnahmen bei Vorkommen gefährdeter Arten mit spezifischen Habitatansprüchen (z.B. Knoblauchkröte, Wiesenweihe, s. DZIEWIATY & BERNARDY 2010, HÖTKER et al. 2009),
Berücksichtigung allgemeiner Bewirtschaftungsgrundsätze zum Schutz seltener Ackerrücksichtigung allgemeiner Bewirtschaftungsgrundsätze zum Schutz seltener Ackerkrautgesellschaften (s. VAN ELSEN et al. 2009),
Aus den notwendigen Handlungserfordernissen ergeben sich die folgenden Anforderungen an die betroffenen Sektoren zur Minimierung der Gefährdungsbelastung der hochgradig gefährdeten Agrarbiobiodiversität:
Landwirtschaft: Berücksichtigung von Artenschutzmaßnahmen bei der Bewirtschaftung,
Naturschutzpolitik: naturschutzfachliche Konkretisierung der Mindestanforderungen zur Umsetzung von Naturschutzmaßnahmen im Rahmen von Agrarsubventionen (z.B. durch die „Greening“-Prämie der Gemeinsamen Agrarpolitik, OPPERMANN et al. 2013); finanzielle Aufstockung von Ausgleichszahlungen zur Durchführung von Artenschutzmaßnahmen; stärkere Regionalisierung geeigneter Förderinstrumente und der „guten, fachlichen Praxis“ sowie der Ausgestaltung des EEG (PETERS et al. 2010),
Raum-/Landschaftsplanung: Berücksichtigung von Anpassungsmaßnahmen des Naturschutzes bei der Landschaftsplanung (v.a. Ausbau des Biotopverbunds, Ausweisung von für den Naturschutz bedeutsamen Vorrangflächen etc.),
Energiewirtschaft: Berücksichtigung von Artenschutzbelangen beim Ausbau erneuerbarer Energien (v.a. Abstandsregelungen bei Windenergieanlagen),
Naturschutz: stärkere Aufklärung von Landwirten hinsichtlich artgerechter Bewirtschaftungsmaßnahmen.

Forschungsbedarf

3.6 Grünland
Direkte und indirekte Auswirkungen des Klimawandels
Aufgrund der klimawandelbedingten Habitatveränderungen wird das Gefährdungsrisiko für


**Handlungserfordernisse und Anforderungen an Sektoren**

Die klimawandelbedingten Handlungserfordernisse zum Schutz gefährdeter Arten in Grünlandökosystemen beinhalten vor allem Maßnahmen zur Förderung der Anpassungsfähigkeit der Arten und Verbesserung des Lebensraumangebots. Dabei sind die folgenden Handlungen vorrangig:

- Erhaltungsmaßnahmen: Verzicht auf Maßnahmen, die eine Veränderung der Standortverhältnisse bewirken (v.a. Entwässerung); standortgerechte Nutzung unter Berücksichtigung der Erhöhung der Strukturvielfalt zur Ermöglichung von Ausweichbewegungen für empfindliche Arten (z.B. gestaffelte Mahdtermine und Belassen ungenutzter Teilflächen),
- Anlage von Pufferzonen (Mindestbreite 10 m): v.a. im Umfeld nährstoffarmer Habitate zur Vermeidung von Nährstoffeinträgen,
- Renaturierung von Grünland: Erhöhung des Flächenangebotes zur Förderung einer Ausbreitung von Arten und Verbesserung des Lebensraumangebots,
- Ausbau des Offenland-Biotopverbundsystems (s. REICH et al. 2012),
Berücksichtigung von Artenschutzbelangen beim Ausbau erneuerbarer Energien (v.a. Erhaltung notwendiger Mindestabstände zu Lebensräumen kollisionsgefährdeter Vogelarten; temporäre Abschaltvorgänge in Phasen mit hoher Fledermausaktivität, s. BRINKMANN et al. 2011),

Monitoring: Überwachung der Bestandsentwicklung klimawandelsensitiver Indikatorarten des Grünlandes,

Wiederherstellung naturnaher Bodenfeuchteverhältnisse,

Auenrenaturierung zur Schaffung naturnahen Feuchtgrünlandes.


Forschungsbedarf

Es besteht dringender Bedarf, den Einfluss des Klimawandels auf Grünlandarten und -habitaten verstärkt durch experimentelle Studien und Feldanalysen sowie Langzeitbeobachtungen von Lebensgemeinschaften und Indikatorarten zu erfassen, um darauf aufbauend detailliertere Schutzmaßnahmen zu entwickeln. Dabei ist die Erforschung der folgenden Faktoren besonders erforderlich:

- Auswirkungen unterschiedlicher Nutzungen auf Habitat- und Artebene unter Einfluss des Klimawandels,
- Veränderung des Nährstoffkreislaufs und die dadurch bedingten Auswirkungen auf das Ökosystem,
- Auswirkung der Interaktion anderweitiger Gefährdungen mit den Effekten des Klimawandels auf gefährdete Arten,
- Analyse von Habitaten und Räumen mit dringendem Handlungsbedarf,
- Analyse der Wirksamkeit von Maßnahmen zur Erhöhung der Anpassungskapazität von Lebensräumen und Arten,
- Einfluss veränderter Abflussverhältnisse auf Auenlebensräume,
Verbesserung des Kenntnisstands zu den Auswirkungen des Ausbaus erneuerbarer Energien (v.a. Windenergieanlagen) auf Lebensgemeinschaften und Ökosysteme des Offenlandes.

3.7 Moore

Direkte und indirekte Auswirkungen des Klimawandels


Handlungserfordernisse und Anforderungen an Sektoren

Zum Schutz von durch den Klimawandel gefährdeten Moorarten bzw. moortypischen Lebensgemeinschaften müssen die verbliebenen Moorlebensräume vor negativen Habitat-

- Wiedervernässung und Renaturierung zur Erhöhung der Resilienz gegenüber veränder-ten Umweltbedingungen,
- standortspezifische Nutzungskonzepte oder Pflegemaßnahmen innerhalb genutzter Be-stände: Berücksichtigung von Maßnahmen zur Erhöhung der Strukturvielfalt (z.B. unter-schiedliche Nutzungen auf Teilflächen) zur Ermöglichung von Ausweichbewegungen,
- Einrichtung von Pufferzonen zu angrenzenden intensiv landwirtschaftlich genutzten Flä-chen,
- Ausbau des Feuchthabitat-Biotopverbundsystems (s. REICH et al. 2012),
- Berücksichtigung von Artenschutzbelangen beim Ausbau erneuerbarer Energien (v.a. Einhalten erforderlicher Mindestabstände zu bedeutenden Vogellebensräumen, s. LAG VSW 2015),
- Monitoring geeigneter Indikatorarten zur langfristigen Analyse der Auswirkungen des Klimawandels auf Arten.


In der Energiepolitik sind rechtliche Rahmenbedingungen zu entwickeln, die einen aus Sicht des Artenschutzes konfliktarmen Ausbau erneuerbarer Energien in der Landschaft fördern. Dies könnte beispielsweise durch höher vergütete Ausgleichszahlungen im Rahmen spezi-scher Schutzmaßnahmen und strengere Regelung der Mindestkriterien von Förderprämien im Sinne der Gemeinsamen Agrarpolitik (s. OPPERMANN et al. 2013) geleistet werden.

**Forschungsbedarf**

3.8 Zwergstrauchheiden

Direkte und indirekte Auswirkungen des Klimawandels


Handlungserfordernisse und Anforderungen an Sektoren


Viele gefährdete heidetypische Arten sind auf einen Verbund von Heideflächen angewiesen, da sie auf den Klimawandel durch Arealverschiebungen reagieren (REICH et al. 2012). Ein Ausbau des Biotopverbunds ist daher besonders notwendig, um Ausweichbewegungen bzw. großflächige Arealveränderungen zu unterstützen. Gleichzeitig sind Renaturierungsmaß-
nahmen besonders erforderlich, um das Flächenangebot zur Stärkung der Populationsgrö-
ßen von Arten zu erhöhen und die Anpassungskapazität an die veränderten Umweltbedin-
gungen zu stärken (BORCHARD et al. 2013). Ein Monitoring und verstärkte Untersuchungen
gefährdeter Arten, für die zusätzlich eine Gefährdung durch den Klimawandel angenommen
wird, sollten angestrebt werden, um die Auswirkungen des Klimawandels auf Lebensge-
meinschaften der Heiden besser zu verstehen und entsprechende Handlungserfordernisse
abzuleiten.

Zur Vermeidung von Beeinträchtigungen durch den Ausbau erneuerbarer Energien (v.a.
Windenergieanlagen und Photovoltaik-Anlagen) ist eine rücksichtsvolle Standortplanung
erforderlich, um die Gefährdungsbelastung für die Artenvielfalt zu reduzieren.

Aufgrund des erhöhten Flächenbedarfs zum zukünftigen Schutz von Zwergstrauchheiden
durch die Ausweitung von Flächen, Anlage eines Biotopverbundsystems und Erweiterung
von Pufferzonen ergeben sich spezielle Anforderungen an die Landschaftsplanung und
Landwirtschaft. Die Berücksichtigung klimawandelbedingter Naturschutzbelange ist in Land-
schaftspläne zu integrieren. Im besten Falle sollte eine Extensivierung der Landnutzung im
weiteren Umfeld bestehender Flächen angestrebt werden, um die Gefährdungsbelastung durch
Nährstoffeinträge zu reduzieren. Ein Ausbau der Solar- und Windenergie in konfliktnah-
men Räumen sollte seitens der Energiepolitik und Landschaftsplanung angestrebt werden.
Zum Schutz und zur Optimierung von Feuchtheiden dürfen Grundwasserentnahmen zur Be-
wässerung oder zur Trinkwassergewinnung nicht erhöht werden, sondern sollten nach Mög-
llichkeit reduziert oder gänzlich eingestellt werden.

Forschungsbedarf
Zur Entwicklung artspezifischer Schutzmaßnahmen besteht besonderer Handlungsbedarf für
die Naturschutzforschung, klimawandelbedingte Auswirkungen auf Arten zu erkennen und zu
analysieren, um anhand der Erkenntnisse konkrete Schutzmaßnahmen zu entwickeln. Erfor-
derlich sind vor allem Felduntersuchungen zur Überprüfung der Ergebnisse bereits vorlie-
gender Sensitivitätsanalysen hinsichtlich des Klimawandeleinflusses auf Heiden und heide-
typische Arten. Dabei ist es notwendig, die Forschung verstärkt auf Artengruppen zu richten,
die hinsichtlich der Auswirkungen des Klimawandels weniger gut untersucht sind (z.B. Lauf-
käfer, Farne). Des Weiteren sind verstärkte Untersuchungen zu den interaktiven Effekten
unterschiedlicher klimawandelbedingter Faktoren (z.B. Erwärmung und erhöhte Niederschlä-
ge im Winter) auf Heiden bzw. heidetypischen Arten erforderlich. Da viele heidetypische Ar-
ten besonders kleinflächig verbreitet sind bzw. kleine Populationen aufweisen, ist die Ermitt-
lung der Mindestpopulationsgrößen und des Flächenbedarfs zur langfristigen Erhaltung der
Arten erforderlich. Aufgrund der regional unterschiedlich starken Veränderung des Klimas in
Abhängigkeit vom Naturraum ist vor allem die Identifizierung von Schwerpunkträumen mit
besonderem Handlungsbedarf erforderlich.

3.9 Wälder

Direkte und indirekte Auswirkungen des Klimawandels

Die mit dem Klimawandel verbundene Temperaturerhöhung und die klimawandelbedingten
Veränderungen im Wasserhaushalt werden mittel- und langfristig die Wälder in Deutschland
beeinflussen und verändern. Während die heimischen Laubbaumarten allenfalls nur gering
durch den Klimawandel gefährdet sind, wird die Gefährdung der heimischen Nadelbaumar-
ten als hoch eingestuft (KÖLLING & ZIMMERMANN 2007). Für heimische Laubgehölze, die
empfindlich gegenüber Trockenstress sind (z.B. Rotbuche Fagus sylvatica), ist vor allem
innerhalb niederschlagsarmer Regionen und auf trockenen und flachgründigen Böden mit
einem Vitalitätsverlust durch zunehmende Sommertrockenheit zu rechnen (MICHELOT et al.
einer zunehmenden Erwärmung werden vor allem Feuchtwälder wie Moor- oder Auenwälder


Handlungserfordernisse und Anforderungen an betroffene Sektoren


Im Zuge der zunehmenden Nutzung von Wäldern als Windenergiestandorte und zur Energieholzgewinnung müssen Artenschutzbelange entsprechend berücksichtigt werden. Hierzu gehören vor allem die folgenden Handlungserfordernisse:

- rücksichtsvolle Standortplanung im Zuge des Ausbaus der Windenergie durch Berücksichtigung ausreichend großer Abstände zu bedeutenden Fledermaushabitaten bzw. zu Lebensräumen sowie Brut- und Rastplätzen kollisionsgefährdeter Vogelarten (Hurst et al. 2016, LAG VSW 2015),
- temporäres Abschalten von Windenergieanlagen in Phasen mit hoher Fledermausaktivität (Brinkmann et al. 2011) bzw. während des Vogelzuges,
- Verzicht auf intensive Maßnahmen zur Holzgewinnung innerhalb von für den Artenschutz bedeutsamen Waldhabitaten,


**Forschungsbedarf**

Es besteht dringender Forschungsbedarf, die Eignung forstlicher Anpassungsmaßnahmen (z.B. Baumartenwahl, Herkünfte von Arten, Anbau- bzw. Erntemethoden; s. Konnert 2007,
KÖLLING et al. 2008) und die Anpassungsfähigkeit heimischer Baumarten an den Klimawandel weitergehend zu untersuchen. Darauf aufbauend sind Analysen notwendig, die die Auswirkungen geeigneter Anpassungsmaßnahmen auf die Biodiversität in Wäldern beurteilen und die Grundlage für naturschutzfachliche Empfehlungen bilden.

Die direkten Auswirkungen des Klimawandels auf gefährdete Waldarten sind bislang nur wenig untersucht. Neben Untersuchungen zu den langfristigen Auswirkungen des Klimawandels ist ein verstärkter Fokus auf die kurzfristigen Auswirkungen des Klimawandels erforderlich, die sich beispielsweise durch Strukturveränderungen und Änderungen der Artengemeinschaften in der Kraut- und Strauchschicht bemerkbar machen.


3.10 Alpine Habitate

Direkte und indirekte Auswirkungen des Klimawandels


Handlungserfordernisse und Anforderungen an betroffene Sektoren


Die Belange des Artenschutzes sind bei der Ausgestaltung von Landschaftsplänen zu berücksichtigen. Gebiete mit Renaturierungspotenzial sind zu identifizieren und landschaftspla-
nerisch zu sichern. Bezüglich des Tourismus besteht dringender Bedarf, verstärkt Aufklä-
rungsarbeit zu leisten und Freizeitnutzer hinsichtlich der negativen Auswirkungen auf alpine Lebensräume zu informieren und Maßnahmen zur Reduzierung von Störungen anzustreben. Aus Sicht der Wasser- bzw. Landwirtschaft ist auf eine Entwässerung bzw. auf Maßnahmen, die eine Entwässerung alpiner Feuchtgebiete bewirken, zu verzichten.

Forschungsbedarf

Zu den Auswirkungen des Klimawandels auf alpine Habitate und die hier verbleibenden
Arten besteht noch ein erheblicher Forschungsbedarf. Auch wenn viele Langzeit-Analysen
zur Entwicklung der Vegetation vorliegen, sind weitergehende Studien zum Einfluss des Kli-
mawandels auf alpine Arten (insbesondere Tiere) und Habitate erforderlich, um spezifische
Schutzmaßnahmen abzuleiten. Es ist vor allem notwendig, Arten und Habitate mit prioritä-
rem Handlungsbedarf zu identifizieren. Als Orientierung dienen die im Rahmen des Vorhab-
bens ausgewählten und als klimasensitiv eingestuften Arten (s. STREITBERGER et al. 2016).
Außerdem ist es notwendig, die Wirksamkeit von Anpassungsmaßnahmen des Naturschut-
zes (z.B. Verbesserung der Habitatkonkretivität, Maßnahmen zur Erhöhung der Strukturviel-
falt) auf die Bestandssituation gefährdeter Habitate und Arten durch ein Monitoring relevanter
Indikatorarten zu überprüfen. Des Weiteren ist der Klimawandeleinfluss auf Ökosystem-
Prozesse und die sich daraus ergebenden Auswirkungen auf Lebensgemeinschaften in alpi-
nen Ökosystemen bislang noch wenig untersucht. Dies gilt ebenso für die indirekten Folgen
des Klimawandels. Die Auswirkungen Klimawandel bedingter Anpassungsmaßnahmen, vor
allem seitens des Tourismus (z.B. Zunahme des Wandertourismus durch Verlängerung der
Vegetationsperiode, verstärkter Einsatz von Kunstschnee), müssen tiefergehend auf gefähr-
dete Arten und Ökosysteme untersucht werden.

3.11 Bauwerke

Indirekte Auswirkungen des Klimawandels

Durch energetische Sanierungsmaßnahmen an Gebäuden, welche eine Energieeinsparung
zum Ziel haben und somit indirekt mit dem Klimawandel verbunden sind, gehen Nistplätze
gläubigebrütender Vogelarten (z.B. Mauerschläger Apus apus, Mehlschwalbe Delichon urbica)
und Quartiere von Fledermäusen oft ersatzlos verloren, wenn entsprechende Schutzmaß-
nahmen nicht ausreichend und rechzeitig bei der Bauplanung durchgeführt werden (MAU-
RER-WOHLATZ et al. 2011). Zu einem Verlust von Fledermausquartieren kommt es in Folge
vorderer Wärmesenierung vor allem an Gebäudevorsassen durch die Anlage von Wärmemind-
verbundsystemen (PETERSEN & KREBS 2012). Durch die Sanierung von Dachgeschossen
gehen außerdem oftmals Einflugöffnungen von Quartieren verloren oder die klimatischen
Bedingungen ändern sich, was sich negativ auf dachgeschossbewohnende Fledermausarten
auswirkt. Zum Schutz von Fledermäusen bzw. anderer gebäudenutzender Arten müssen
daher bei Gebäudesanierungen diverse Schutzmaßnahmen berücksichtigt werden. Insbes-
ondere für viele Fledermausarten liegen Hinweise auf eine Klimawandelempfindlichkeit an-
hand der ausgewerteten Studien vor (z.B. Mopsfledermaus Barbastella barbastellus, Nordfel-
dermaus Eptesicus nilssonii, Zwergfledermaus Pipistrellus pipistrellus, Zweifarbfledermaus
Vespertilio murinus; BEHRENS et al. 2009a, JAESCHEKE et al. 2014, KERTH et al. 2014). Daher
werden im Folgenden vor allem Handlungserfordernisse zum Schutz von Fledermäusen bei
der Gebäudesanierung vorgestellt.

Handlungserfordernisse und Anforderungen an Sektoren

Nach Möglichkeit sollten Maßnahmen getroffen werden, die Quartiere und die entsprechen-
den Zugänge oder Nistplätze zu erhalten. Dies ist besonders erforderlich, wenn keine Aus-
weichquartiere im näheren Umfeld bestehen oder keine Ersatzquartiere angelegt werden
können sowie bei Vorkommen von Arten, die bislang nur selten in Fledermauskästen nach-
gewiesen werden (z.B. B. barbastellus, V. murinus). Insbesondere die Lage der Einflugöff-
nungen spielt eine entscheidende Rolle für Fledermäuse. Diese sollten nach Möglichkeit an der ursprünglichen Stelle beibehalten werden, um die Wahrscheinlichkeit einer Wiederbesiedlung nach Beendigung der Arbeiten zu erhöhen.


Forschungsbedarf


Des Weiteren sind die folgenden Fragestellungen für den Schutz von Fledermäusen im Zuge der zunehmenden energetischen Gebäudesanierung und des Klimawandels von besonderer Bedeutung:

- Wie lässt sich das Gefährdungsrisiko für betroffene Fledermausarten durch Sanierungsmaßnahmen vermeiden bzw. wie kann evtl. Quartiersverlust ausgeglichen werden?
• Wie lassen sich Fledermäuse, die ganzjährig an Gebäuden vorkommen, während der Bauphase artgerecht vergrämen, ohne dass sie dabei zu Schaden kommen?
• Wie wirkt sich die zunehmende Erwärmung auf die Quartiernutzung und Überwinterung von Fledermäusen aus?

In Folge der Erwärmung wird die Ausbreitung mesophiler Arten in Moorlebensräumen wie Kalkflachmooren gefördert.
As a result of global warming mesophilous species are promoted within mire ecosystems like calcareous fens.

(Foto / Photo: Thomas Fartmann)
4 Fazit

Handlungserfordernisse des Artenschutzes


Forschungsbedarf

An den Klimawandel angepasste artspezifische Maßnahmen lassen sich bislang nur in wenigen Fällen ableiten, da die Wirkung des Klimawandels auf die meisten Arten noch unzureichend bekannt ist. Insbesondere das Zusammenwirken unterschiedlicher klimawandelbedingter Effekte auf der Populationsebene ist noch wenig untersucht. Während beispielsweise viele Libellenarten von einer Erwärmung und Verlängerung der Vegetationsperiode profitieren, steigt das Austrocknungsrisiko von Kleingewässern durch die Zunahme von Trockenperioden (OTT 2012). Neben dem Einfluss physiologischer Änderungen und Habitatverände-

Neben den direkten Auswirkungen des Klimawandels auf Arten ist es dringend erforderlich, den Einfluss klimawandelbedingter Lebensraumveränderungen auf Artengemeinschaften und betroffene Arten verstärkt zu analysieren. Dies gilt vor allem für wasserabhängige bzw. aquatische Systeme, für die aufgrund der starken Habitatveränderungen erhebliche Auswirkungen der Lebensgemeinschaften prognostiziert werden.


Key points for an action plan for species conservation under climate change in Germany

1 Introduction

1.1 Climate change in Germany

Due to increasing greenhouse gas emissions since the beginning of the industrialization humans have significantly influenced climate (EEA 2012). As a consequence, global mean temperature increased by 0.85 °C during the past century (IPCC 2013). In Germany, mean annual temperature increased by 0.8–1 °C in the period between 1901 and 2000 (JONAS et al. 2005, RAPP 2000, UBA 2006 a, b). Especially within the warmest regions such as the southwestern part of the country recent warming is above average (ZEBISCH et al. 2005).

However, for precipitation no trend has yet been observed. While annual precipitation was more or less constant over the past years there is a tendency that summer precipitation is decreasing and winter precipitation is increasing (LEUSCHNER & SCHIPKA 2004, ZEBISCH et al. 2005). Besides warming, extreme weather events have become more frequent recently. Especially the frequency and duration of heat waves have increased, particularly in the southwest and northeast of Germany (GERSTENGARBE & WERNER 2009). However, for storm and heavy rainfall events no clear trend has yet been observed (GERSTENGARBE & WERNER 2009).

Depending on the future scenario an increase in mean annual temperature by 1.5–3.7 °C is predicted for Germany for the end of the 21st century compared to the reference period 1951–2000 (SPEKAT et al. 2007, UBA 2006a). Thereby, temperature increase will be stronger in winter than in summer (SPEKAT et al. 2007). For most parts of Germany, a shift of precipitation from summer to winter is forecasted. In dependence of the scenario, a decrease of summer precipitation of 20–30 % is predicted (UBA 2006a). This especially holds true for the warmest regions in Germany. However, due to the great regional variability forecasts on precipitation are much more uncertain than projections on temperature development.

In the course of climate change, the frequency of extreme weather events such as heat waves and drought periods will increase. For the mid-century GERSTENGARBE & WERNER (2009) expect a significant increase of summer days compared to the reference period (1951–2006). Especially within the hottest regions in Germany an increase of the frequency of heat waves is predicted. Additionally, a strong decrease of summer precipitation is forecasted, especially for the eastern part of Germany. Therefore, drought periods will occur more frequently. In contrast, heavy rainfall events (days with precipitation sums ≥ 10 mm) are predicted to occur more often within the northwestern part of Germany (GERSTENGARBE & WERNER 2009).

1.2 Effects of climate change on biodiversity

Since the end of the last century research on the effects of man-made climate change on biodiversity and the extinction of species is continuously increasing (LEUSCHNER & SCHIPKA 2004). Recent climate change has manifold impacts on species communities and biodiversity. Besides changes in temperature and precipitation the increase of extreme weather events such as heavy rainfall or long lasting drought periods have dramatic consequences for biodiversity (cf. BEIERKUHNLEIN & JENTSCH 2013).

Thereby, the following effects influence species and cause changes within species communities (ESSL & RABITSCH 2013, MOSBRUGGER et al. 2014):
• developmental (e.g. metabolic changes or altered reproduction success) and behavioral changes of species,
• phenological shifts,
• altered biotic interactions (e.g. by phenological or spatial mismatch of interacting species),
• range shifts (changes of species communities, extinction of species),
• habitat shifts.

Due to the significant impact of global warming it is expected that the effects of climate change will have a more severe influence on biodiversity compared to habitat changes caused by humans (LEUSCHNER & SCHIPKA 2004). In addition to the direct effects of climate change by altered temperature or precipitation conditions, indirect effects also have an impact on biodiversity. These effects result from forestal or agricultural adaptation strategies and political decisions such as the expansion of renewable energies for increasing the use of CO₂-neutral energy resources.

The development of adaptation strategies for mitigating the negative effects of climate change is also important for species conservation (DAS 2008). However, as the consequences of climate change on biodiversity will be inevitable there is not only demand for developing adaptation strategies. In the long run, it is also necessary to redefine the targets of nature conservation (IBISCH & KREFT 2008, KUNZE et al. 2013, WILKE et al. 2011). In the course of global warming, the conservation of current species communities will require high efforts.

With respect to species conservation, supporting the adaptability of habitats and species to environmental changes is an important strategy for preventing species loss (IBISCH & KREFT 2008). This holds especially true for rare and highly threatened species which are negatively affected by climate change. In addition to that, the implementation of species-specific conservation measures is essential for protecting species which are endangered by the indirect effects of climate change, such as the increased use of renewable energies or agricultural adaptation strategies.

1.3 Aims of the project

Due to the strong impact of climate change on biodiversity several research projects were funded by the German Federal Agency Nature for Conservation (BfN) for analyzing the direct and indirect effects of climate change on biodiversity and for developing adaptation strategies for nature conservation. The aim of this research and development project was the synthesis of the results of all relevant BfN projects for developing a climate change related action plan for the conservation of habitats and species vulnerable to climate change. Thereby, the project refers to recent climate change characterized by a continuous temperature rise and altered precipitation conditions. The development of the concept was based on a summary of the results of several research projects which were funded by the BfN during the past ten years and comprise analyses on the direct and indirect effects of climate change on species and nature conservation. In addition to that, an extensive literature review on the subject was carried out. Based on the results of the analyses an action plan for species conservation under climate change was derived. The action plan focuses on threatened species which are characterized by a high vulnerability to climate change and habitats of conservation concern. In addition to action strategies, the relevant sectors for implementing the essential conservation measures are specified. Furthermore, important issues for further research are summarized with respect to species conservation under climate change. In the present publication, the main results of the action plan are summarized. The full results of the project are published in STREITBERGER et al. (2016).
2 Methods for the development of the action plan

For the development of the action plan current knowledge on the effects of climate change on habitats with a high significance for species conservation was reviewed. Furthermore, we selected endangered species vulnerable to climate change which were considered in more detail within the action plan. The species selection was based on several studies and BfN projects which evaluated or predicted the influence of climate change on selected species in Germany (BEHRENS et al. 2009a, HANSPACH et al. 2013, JAESCHKE et al. 2014, KERTH et al. 2014, KREFT & IBISCH 2013, POMPE et al. 2011, RABITSCH et al. 2010, SCHLUMPRECHT et al. 2010, TRAUTMANN et al. 2013). Within the action plan the following species groups are regarded: vascular plants, fish, amphibians, reptiles, birds, mammals, dragonflies, Orthoptera, ground beetles, butterflies and burnet moths, land snails and freshwater molluscs. The action plan comprises the analysis of the final reports of relevant BfN projects (cf. STREITBERGER et al. 2016). Additionally, a literature review was carried out in the year 2014 in order to document the current state of knowledge on the climate change effects on the selected habitats and species. The literature research was based on international and national publications of the past ten years with special focus on Central Europe and was carried out using the data bases *isi web of science* and *DNL-online*.


Some invasive alien species benefit from global warming and displace native species (e.g. cord-grass [Spartina anglica] the glass-wort [Salicornia stricta] in the Wadden Sea).

(Foto / Photo: Stefan Nehring)
3 Results: Action plan

3.1 Marine and coastal habitats

Direct and indirect effects of climate change

Besides ocean warming altered hydrochemical conditions such as acidification or changes of salinity are significant effects of climate change which influence marine and coastal ecosystems (cf. NARBERHAUS et al. 2012). In contrast, predicted sea level rise poses a severe threat to coastal habitats such as tidal flats or supra- and epilitoral habitats (e.g. salt meadows) (WILTSHEIRE & KRABERG 2013). Furthermore, strong climate change effects are expected for ecosystems composed of key species with a high vulnerability to environmental changes such as eelgrass meadows (cf. NARBERHAUS et al. 2012).

Additionally to the direct effects of climate change, the expansion of offshore wind farms evokes substantial changes within marine ecosystems, for example by the creation of artificial reefs at the base of wind turbines (LANGHAMER 2012, BERGSTRÖM et al. 2014, BSH & BMU 2014). Furthermore, pile driving causes physical damages of the hearing organs of sea organisms (especially mammals), when mitigation measures are neglected (BERGSTRÖM et al. 2014, BSH & BMU 2014).

Action plan and sectoral demands

Most consequences of climate change (especially hydrochemical changes and sea warming) are inevitable. Therefore, changes within species communities must be accepted by nature conservation. A flexible orientation of marine species conservation is therefore essential. The implementation of measures increasing the resilience and adaptability of marine and coastal ecosystems and species to environmental changes is of high importance for decreasing the extinction risk of habitats and species vulnerable to climate change (CPSL 2001). Thereby, relevant actions comprise the monitoring of indicator species for documenting climate change effects on species communities, the mitigation of existing threats (e.g. negative effects of wind farms or fishery), the improvement of habitat connectivity (especially along the coast) and the promotion of dynamic processes (e.g. by managed realignment).

For the mitigation of negative effects by fishery it is obligatory to implement an ecologically orientated fishery aiming at the conservation of sustainable populations. For the European Union, the Common Fisheries Policy (CFP 2014) demands a population recovery above the species-specific threshold which guarantees a sustainable catch size. Furthermore, negative impact on marine ecosystems must be prevented by fishery. Especially, the use of fishing tools damaging the ocean floor such as demersal trawling must be reduced. Within protected areas these techniques should be completely banned.

Additionally, it is important to control the distribution of invasive alien species. As a cause of ocean warming alien thermophilous species are promoted which have the potential to repress native species. In order to identify invading alien species at an early stage, the monitoring of species communities within hotspots of species introduction such as ports or estuaries is of special importance (NEHRING et al. 2009, OJAVEER et al. 2014). Furthermore, guidelines regulating the handling of alien species (cf. OJAVEER et al. 2014) must be respected by aquaculture and shipping.

The following sectoral demands exist for the implementation of relevant measures for mitigating the negative effects of climate change on threatened marine and coastal ecosystems and species:

- fishery/shipping: sustainable fishing; prevention of the introduction and dispersal of alien species,
- aquaculture: consideration of guidelines regulating the handling of alien species,
• politics: implementation of environmental demands within fishery policies; stricter regulations for preventing the introduction of alien species,

• landscape planning/coastal defense: consideration of nature conservation aims within landscape plans with respect to climate change and essential adaptation strategies (e.g. implementation of measures promoting natural processes such as managed realignment),

• power industry: implementation of species conservation measures during the planning and construction of wind energy farms.

Further research

For identifying the long-term effects of climate change on coastal and marine species communities there is urgent need to identify species which are affected by climate change and, therefore, function as indicator species. Hence, further analysis on the adaptability of marine species to environmental changes is of special concern for deriving specific conservation measures. Besides the direct effects of sea warming on species, the cumulative impact of different climate change effects such as sea warming and acidification on species communities has yet been hardly analyzed and requires more specific studies (cf. PÖRTNER 2006).

For sustainable coastal protection measures such as managed realignment the development of practical strategies from a social and planning viewpoint is of special importance. Furthermore, the ecological impact of sand nourishment measures must be increasingly analyzed from an ecological viewpoint (CPSL 2010).

Additionally, there is an increasing demand for analyzing the impact of offshore wind farms on marine ecosystems and species for improving existing conservation measures such as noise mitigation measures during pile driving. Especially long-term studies comparing the development of species communities within wind farms to reference sites are essential for comprehending the impact of offshore wind farms on biodiversity and for specifying existing conservation strategies.

Finally, the influence of climate change on the invasion of alien species requires more detailed analyses for developing strategies to mitigate negative effects of invasive species on marine biodiversity (cf. KATSANEVAKIS et al. 2014, OJAVEER et al. 2014). Thereby, it is especially important to investigate the survival and dispersal strategies of invasive species and to analyze the anthropogenic influence on the distribution on these species. This holds especially true for insufficiently investigated taxa such as microorganisms.

3.2 Rivers and springs

Direct and indirect effects of climate change

Increasing water temperatures, altered discharge and hydrochemical conditions (e.g. higher solubility of nutrients caused by water warming) are the main climate change related effects influencing species communities within river and spring ecosystems (cf. HAASE et al. 2012). Especially for cold-adapted species and species distributed within the upper reaches of streams there is an increased risk of threat caused by rising water temperatures (MELCHER et al. 2013). As a consequence of warming, a potamalization of upstream river reaches is triggered by the expansion of potamal species (HAASE et al. 2012, MATULLA et al. 2007). Especially within mountain rages, where a shift of river zones is limited, the extinction risk is regarded as high for species distributed within the upper reaches of streams (DURANCE & ORMEROD 2007). Besides warming of the water body, altered discharge conditions caused by changes in precipitation have influence on river and spring ecosystems. For a great proportion of rivers in Germany, reduced amounts of discharge are forecasted due to a reduction of summer precipitation (HAGEMANN & JACOB 2007, PRANGE et al. 2013). As a consequence,
substantial changes of species communities are predicted for stream ecosystems. Especially for mussels and species dependent on course water beds the risk of extinction increases due to the raised deposition of fine sediments caused by reduced discharge (PRANGE et al. 2013, VERDONSCHOT et al. 2010). With respect to stenotopic spring species the extinction risk is predicted to be extremely high due to drying up of springs caused by prolonged drought periods in summer (WINTER & SCHINDLER 2011). In contrast, an increase in the frequency of heavy rainfall events and higher winter precipitation is predicted so that extreme water levels and flooding events will occur more frequently (cf. HAASE et al. 2012, VERDONSCHOT et al. 2010).

In addition to the direct effects of climate change indirect consequences of climate change increase the vulnerability of stream ecosystems. Due to the high demand for land in line with agricultural intensification and increased cultivation of energy crops there is a high risk that water pollution increases by higher nutrient and pollutant inputs. This effect may be even enhanced by the direct effects of climate change, e.g. by heavy rainfall and increased run-off (HAASE et al. 2012, SCHOLZ et al. 2013). Furthermore, due to prolonged periods of summer drought the agricultural demand for water is raised which results in increased water extraction from ground and surface waters with negative effects on river ecosystems (WILKE et al. 2011).

According to political decisions on expanding the use of renewable energies, an increased use of hydrodynamic power is likely. As a consequence of this, longitudinal connectivity may be further restricted when mitigation measures are inefficient or neglected. Due to changes in discharge, there is an increased demand for the modification of existing hydroelectric power stations (cf. WOLF-SCHUMANN & DUMONT 2010). At present, the ecological consequences are not predictable due to the uncertain forecasts on the regional precipitation regime. In every case, negative impacts will arise for migrating water organisms when the longitudinal connectivity is increasingly restricted due to the further construction of dams. Thereby, not only migration but also local movements of water organisms are restricted whereby the adaptability of species to environmental changes is limited.

**Action plan and sectoral demands**

For the conservation of highly threatened species of rivers and springs under climate change the following actions are necessary:

- protection of natural rivers and streams,
- restoration of rivers and floodplains,
- promotion of synergistic effects of conservation and flood control: creation of retention sites for flood control,
- improvement of water quality (e.g. by buffer strips and low-intensive use of agricultural sites adjacent to water bodies),
- reduction of the discharge of cooling water,
- measures for preventing the dehydration of springs (e.g. measures for increased groundwater accumulation or spring flow).

For the implementation of these measures the following sectoral demands exist:

- water management/power industry: abandonment of river development and the construction of new hydroelectric power stations; development of existing power stations respecting the conservation of longitudinal connectivity; construction of cooling towers (BÖLSCHER et al. 2013),
- agriculture: establishment of buffer zones,
• fishery: prohibition of catching threatened species and prevention of introducing alien species,
• landscape planning: minimization of surface sealing for promoting groundwater accumulation; determination of retention sites for flood control and restoration of floodplains.

Further research

Even though scientific interest for the influence of climate change on river ecosystems has increased during the past years, many aspects are still unknown. Accordingly, species conservation research on the following topics is of special interest in order to derive specific management recommendations with respect to climate change:
• effects of drought periods and low water levels on species communities in rivers and springs: Which threshold values of water levels evoke extinction or migration of species (PRANGE et al. 2013)?,
• effects of climate change on spring fauna,
• effects of isolation on the genetic variability of populations of cold-adapted species,
• effects of climate change on alien species,
• gain of knowledge on the ecological condition of floodplains for the development of site-specific restoration measures (cf. SCHOLZ et al. 2012)
• reaction of migratory fish species during migration at hydroelectric power stations and fish bypasses.

3.3 Lakes

Direct and indirect effects of climate change

The warming of lakes has strong effects on the mixing regime and chemical composition of standing water bodies. Due to warming a seasonal shift or even a discontinuation of seasonal mixing is promoted (cf. ARVOLA et al. 2010, HAASE et al. 2012, KÖHLER 2012). As a consequence of more stable stratification, oxygen concentrations are reduced within the hypolimnion whereby an internal eutrophication is triggered by the mobilization of phosphate (cf. KIRLOVA et al. 2009, VETTER & SOUSA 2012). Furthermore, altered precipitation and temperature conditions especially in winter lead to higher inputs of external nutrients such as nitrate, phosphate or dissolved organic carbon (GEORGE et al. 2010). These physical and chemical processes have significant impact on the primary productivity within lakes. Seasonal shifts of the maximal abundance of phytoplankton are promoted by water warming and increased nutrient availability with substantial effects on phyto- and zooplankton communities (SHATWELL et al. 2008). Especially, for nutrient-poor lake ecosystems (e.g. dystrophic lakes and ponds) the vulnerability to climate change is regarded as high (cf. PETERMANN et al. 2007). Besides temperature and chemical changes, altered precipitation conditions have an impact on standing water bodies. Due to reduced summer precipitation lowered water levels have been measured recently within a wide variety of lakes (e.g. within Northeast Germany and at Lake Constance, cf. DIENST et al. 2008, STÜVE 2011).

Raised water temperatures influence biodiversity within lakes by a great variety of different mechanisms (HAASE et al. 2012). On the one hand, higher water temperatures have a direct impact on the metabolism, growth, reproduction and phenology of water organisms. On the other hand, altered mixing processes influence the elemental and thermal budget of lakes which affects water organisms. Due to climate change the vulnerability is increased for cold-adapted species (e.g. salmonids), mountainous species and species of nutrient-poor ecosystems. Furthermore, as a cause of prolonged summer droughts and increased drying up the extinction risk is regarded as high for rare species which are dependent on regularly flooded
shorelines (e.g. *Myosotis rehsteineri* [Dienst et al. 2008, Ostendorp & Dienst 2009]) and species dependent on small water bodies for reproduction such as many amphibians or dragonflies (cf. Ott 2012). In addition, warm-adapted alien species are promoted by higher water temperatures whereby the risk increases that stenothermic native species are repressed by the more competitive, invading species (cf. Cruz et al. 2008, Gherardi et al. 2013, Klein et al. 2010).

As described for stream ecosystems there is an increased risk that nutrient input is elevated within standing water bodies in consequence of land use intensification. Furthermore, increased withdrawal of water for the irrigation of agricultural systems poses a severe threat for lake ecosystems (cf. Haase et al. 2012, Schädler 2002).

**Action plan and sectoral demands**

For the conservation of lake ecosystems and species vulnerable to climate change it is especially important to reduce existing threats and to promote the adaptability of these ecosystems and species to altered environmental conditions. Thereby, the following measures are of high importance:

- **improvement of water quality:** minimization of nutrient input by the establishment of buffer zones to adjacent agricultural land and by large-scale low-intensive land use on surrounding farmland; measures for reducing nutrient input by influents (NLWKN 2011),
- **removal of sludge and weeds within the shoreline of lakes for promoting low-competitive species dependent on semi-aquatic habitats,**
- **conservation and improvement of a natural water balance:** regulation of water levels within artificial lakes for compensating lowered water tables,
- **increase of habitat heterogeneity by increasing the structural diversity within lakes and shorelines in order to promote the local adaptability of species,**
- **improvement of habitat connectivity (e.g. by the removal of barriers at in- or effluents or the restoration and creation of new standing water bodies), especially within regions with a fragmentary network of water bodies (central and southern Germany, Reich et al. 2012).**

For mitigating the negative effects of climate change on lake ecosystems there are special demands concerning the agricultural sector. In order to minimize the nutrient input into waters it is extremely important that sufficiently large buffer zones (minimum 10 m) are established within agricultural fields bordering standing water bodies. Within areas where the risk of erosion is high (due to climatic or certain soil conditions) the cultivation of crops promoting erosion such as maize or potatoes should be avoided in order to reduce substantial or chemical inputs into waters. Furthermore, the withdrawal of water of standing water bodies for irrigation should be banned. With respect to landscape planning essential adaptation strategies of species conservation to climate change (e.g. improvement of habitat connectivity) must be increasingly integrated within landscape plans.

**Further research**

In recent times, limnological studies mainly focused on the climate change induced effects on the energy budget and chemical composition of lakes. Thereby, primary productivity and the consumption by zooplankton were of special interest. However, knowledge on the climate change effects on species of higher trophic levels is still poor. The same holds true for small (ephemeral) water bodies, which have a high significance for species conservation. Due to increased summer drought these ecosystems are severely threatened by climate change. Furthermore, it is essential to investigate the reaction of organisms to reduced oxygen concentrations within the hypolimnion and how their reactions to climate change induce changes
within species communities. In order to develop management strategies, the analysis of climate change effects on these issues is of special concern.

Furthermore, the effect of a shortened ice cover on species communities has hardly been analyzed. Besides changes in temperature or precipitation, wind is an important determinant for the mixing and ecological conditions of lakes. However, up to now projections on how altered wind conditions influence lake ecosystems are still rare. The same holds true for the reaction of alien species to water warming. Therefore, more detailed research is necessary for analyzing the effect of climate change on alien species.

3.4 Rocks, cliffs, scree slopes and habitats with open soil

Direct and indirect effects of climate change

The effects of climate change on species communities within rocks, cliffs and scree slopes as well as habitats with open soil are mostly unknown. Hence, there is a great demand for research on the climate change effects on these ecosystems in order to derive specific management and conservation strategies. Up to know, climate change effects on threatened species can only be estimated according to the specific habitat demands of species (cf. BEHRENS et al. 2009a).

As a consequence of rising temperature, there is a high extinction risk for species communities typical for undercooled scree slopes. Due to increased winter rainfall and shortened frost periods there is a high risk that the microclimatic conditions within these habitats will change drastically by the warming of the interior air masses and reduced ice formation. Thereby, cold-adapted, arcto-alpine or boreal-montane species within mountain ranges as well as endemic, highly threatened or stenotopic species are negatively affected (cf. BRUNNER et al. 2013, MÖSELER & WUNDER 1999, MÜLLER & MOLENDA 1999). Especially, within low mountain ranges there is an increased risk that characteristic species of undercooled scree slopes decline if warming continues. Due to limited habitat availability, local distribution shifts are restricted. Furthermore, increased drought stress is regarded as a potential threat for endangered species dependent on rocky habitats (cf. SCHEUERER et al. 2007).

With respect to habitats rich in open soil occurring within wet habitats such as floodplains or at the shorelines of water bodies, it is expected that increased drying up due to reduced summer precipitation has a serious impact on hydrophilic species. Similar effects are also expected for species dependent on small water bodies within open habitats such as stone pits (e.g. Yellow-bellied Toad *Bombina variegata* or Common Spadefoot *Pelobates fuscus*, cf. BEHRENS et al. 2009a, DITTRICH & RÖDEL 2014a).

Until now, there is no evidence on how species of open habitats are affected by the indirect effects of climate change. However, due to the increased demand for land (e.g. by the expansion of renewable energies) the extinction risk increases for rare species associated with open habitats when these are negatively affected by land use intensification (e.g. by habitat destruction or changes caused by increased atmospheric nutrient inputs).

**Action plan and sectoral demands**

In order to prevent strong declines of habitats and species under climate change, it is extremely important to mitigate current threats (e.g. by the designation of protected areas, ban of mining within areas of special conservation value, reallocation of rock climbing routes with respect to species conservation aims, management such as shrub removal or grazing within open habitats, ban of hydro-engineering measures within the catchment area of scree slopes; ACKERMANN et al. 2003, BRUNNER et al. 2013, PREISING 1997, NLWKN 2011).

Within abandoned mines artificial recultivation should be banned, especially within sites which function as important habitats for the conservation of threatened species. Succession-
al developments of these sites should be favored by respecting the conservation of special habitat structures (e.g. conservation of ponds as spawning habitats for amphibians, shrub removal for the conservation of open rock habitats).

Furthermore, the increase of habitat heterogeneity (e.g. creation of differently structured and sized ponds as spawning habitats for amphibians) is recommended for promoting the local adaptability of species to environmental changes or extreme climatic events. In order to support range shifts of species on a regional level, it is necessary to improve the connectivity of open habitats. Especially within northern Germany the network of open habitats is too fragmentary for favoring northward shifts of species (Reich et al. 2012). As knowledge on the effects of climate change on species of rocky or open habitats is still very poor, a long-term monitoring of threatened species characteristic for these habitats is essential.

For the implementation of the required actions the following sectoral demands exist:

- **landscape planning**: implementation of the required conservation measures, e.g. designation of protected areas, improvement of local and (supra)regional habitat connectivity, recultivation with respect to conservation aims, abandonment of mining within sensitive areas,

- **forestry**: abandonment of intensive silviculture within wooded scree slopes and their surroundings,

- **rock climbing**: consideration of access bans.

**Further research**

A long-term monitoring of rocky habitats and characteristic species associated with these habitats is necessary in order to identify the effects of climate change. This especially holds true for undercooled scree slopes. For the establishment of monitoring programs, it is important to identify suitable indicator species groups and species. According to the results of the analyses, specific conservation measures must be derived for supporting the adaptability of species communities to climatic changes within open habitats.

### 3.5 Arable habitats

**Indirect effects of climate change**

Due to changes in temperature and precipitation agricultural adaptations strategies are necessary for mitigating the negative effects of climate change on agricultural production. Thereby, impacts on agroecosystems arise from changes in crop selection and intensified land use (cf. Schaller et al. 2014). However, the effect of these changes on species populations within arable ecosystems is still unknown and must be analyzed in more detail by field studies. Besides agricultural adaptation, the expansion of renewable energies poses a severe threat to farmland biodiversity. Especially, the extensive cultivation of energy crops and the increased construction of ground-mounted photovoltaic and wind energy plants increase demand for land and lead to a change of agricultural habitats (GFN & ZSW 2011, Herden et al. 2009). From a conservation viewpoint, the expansion of intensively managed monocultures such as large-scale maize cultivation is adverse (Reich et al. 2011). This holds especially true when intensive weed control is carried out and measures for increasing structural diversity (e.g. field margins with low-intensive land use) are neglected (Tillmann & Krug 2010). For farmland birds – like the Montagu’s Harrier (*Circus pygargus*) – the increasing cultivation of winter cereals for silage production leads to a decline of suitable breeding habitats as harvesting coincides with the breeding period of most species (cf. Niedermeier-Stürzer et al. 2012).

Due to the increased demand for agricultural land fields with marginal yields or abandoned sites which have a high importance for the conservation of agrobiodiversity are increasingly
converted into intensively used fields. This results in the loss of rare and threatened species (SEIFERT et al. 2014). Additionally, perennial crops – such as short rotation coppice – are increasingly cultivated for producing biomass. On the landscape level the establishment of such perennial crops can increase species diversity within monotonous agricultural landscapes (DAUBER et al. 2010, IMMERZEEL et al. 2014, MEYER et al. 2014). However, within heterogeneous landscapes the cultivation of perennial crops may induce species declines (DAUBER et al. 2010). Furthermore, reactions of species to bioenergy crops vary strongly according to the studied species groups and are dependent on crop type (cf. IMMERZEEL et al. 2014). Furthermore, the expansion of wind energy has a severe impact on farmland biodiversity (FLADE 2012, PEARCE-HIGGINS et al. 2009, 2012, ZAHN et al. 2014). The collision risk increases for bat and bird species which forage or breed in agricultural landscapes. Additionally, wind energy plants lead to avoidance reactions of farmland birds.

**Action plan and sectoral demands**

In the course of agricultural intensification, the implementation of measures for increasing habitat diversity in farmland areas is of special importance for the conservation of farmland biodiversity. Thereby the following actions are especially significant:

- abandonment of land use intensification and consideration of specific species conservation measures within sites that function as important habitats for threatened species (e.g. Common Spadefoot, Mantagu’s Harrier, cf. DZIEWIATY & BERNARDY 2010, HÖTKER et al. 2009),
- low-intensive land use for the conservation of rare arable weed communities (VAN ELSEN et al. 2009),
- promotion of biodiversity within intensively used sites such as energy crop systems by specific measures (e.g. conservation of stubble fields during winter, conservation of small-scaled structures such as ponds or species-rich field margins, cf. BFN 2010, DAUBER et al. 2010, GFN & ZSW 2011, NABU 2014, NIEDERMEIR-STÜRZER et al. 2012, REICH et al. 2011, SCHÜMANN et al. 2010),
- consideration of species conservation demands during the establishment and management of solar and wind energy plants by respecting essential minimum distances to habitats of high conservation values (e.g. habitats of threatened breeding birds, cf. LAG VSW 2015) and by a temporary turning-off of wind energy plants during periods of high bat or bird activity, cf. BRINKMANN et al. 2011).

The essential measures for the conservation of farmland biodiversity and for minimizing the extinction risk of highly threatened species result in the following sectoral demands:

- agriculture: consideration of species conservation aims,
- politics: consideration of minimum demands for the implementation of conservation measures in line with agricultural subsidies (e.g. the greening-award of the Common Agricultural Policy, OPPERMANN et al. 2013); financial increase of compensation payments for promoting the implementation of species conservation measures; regionalization of funding systems and the renewable energy sources act (EEG) (PETERS et al. 2010),
- landscape planning: implementation of adaptation strategies of species conservation within landscape plans (e.g. improvement of habitat connectivity),
- power industry: respect of essential species conservation measures during the expansion of renewable energies (especially minimum distances to habitats of high conservation value for site selection),
Further research

Concerning the direct effects of climate change on farmlands and their biodiversity (e.g. by temperature rise, an altered precipitation regime or extreme weather events) our knowledge is extremely poor. Furthermore, the effects of agricultural adaptation strategies such as altered cultivation methods are rarely analyzed with respect to farmland biodiversity. Additional research demand exists for analyzing the effects of the cultivation of novel crops (e.g. perennial or genetically modified crops) and the influence of the expansion of solar plants on biodiversity (DOG & DDA o.J., HERDEN et al. 2009). Furthermore, the impact of wind power plants on biodiversity must be analyzed in more detail for improving specific management options. Therefore, the research on the efficiency of conservation measures must be carried out by increasing long-term and before and after studies, especially concerning the effect of temporary turning-off of power plants and essential minimum distances to important bat habitats.

3.6 Grassland

Direct and indirect effects of climate change

Due to decreasing water levels threatened wet grassland species are regarded as vulnerable to climate change (e.g. Dusky Large Blue Phengaris nausithous, Moor Frog Rana arvalis, Narrow-mouthed Whorl Snail Vertigo angustior) (BEHRENS et al. 2009a, JAESCHKE et al. 2014, KERTH et al. 2014). In addition, montane grassland ecosystems (e.g. mountain hay meadows) and species are threatened by rising temperature and the upward range expansion of warm-adapted lowland species (cf. BEHRENS et al. 2009b, BITTNER & BEIERKUHNLEIN 2014).

The future development of grassland ecosystems is especially dependent on the extent of climatic change and agricultural development. Climate change effects on grasslands differ strongly depending on regional climate and local site conditions. Especially within dry regions there is a high risk that wet grassland communities are negatively affected by prolonged summer droughts. Therefore, the extinction risk of specialized hygrophilous species is assumed to be very high (BEHRENS et al. 2009a). But also within dry grassland communities such as calcareous grasslands higher temperatures and drought periods induce a decline of species sensitive to desiccation (cf. MAALOUF et al. 2012). In contrast, an increase of summer drought is regarded as positive for dry grassland communities as successional speed is reduced with positive effects on characteristic thermophilous and less-competitive species (BEHRENS et al. 2009b). However, within regions with high precipitation successional speed and agricultural land-use are expected to be intensified as a cause of increased productivity by warming and a prolonged vegetation period (ESSL 2013). Hence, the extinction risk of species dependent on low-successional stages will increase. The future use of grasslands is especially dependent on the climatic development (cf. BOCK et al. 2013). Therefore, the implementation of a locally adapted grassland management scheme will determine the composition of species communities. Besides direct effects on species communities, global warming influences ecosystem processes (cf. JENTSCH et al. 2011).

However, the cumulative impacts of different climate change related effects on species communities are still insufficiently understood. This is also true with respect to site-specific effects of climate change. In addition to the direct impact of climate change the increased demand for agricultural land has far-reaching consequences for grassland ecosystems. Recently, as a result of the increased energy crop cultivation permanent grasslands have been extensively converted to arable land for biomass production. Furthermore, wind energy plants have negative impacts on birds and bats by causing collisions or avoidance reactions.

Action plan and sectoral demands

For preventing negative effects of climate change on sensitive grassland species, it is im-
important to support the adaptability of species to environmental changes, improve habitat quality and increase habitat availability. Therefore, the implementation of the following actions is of special importance:

- conservation measures and mitigation of threats, especially:
  - prohibition of drainage and land use intensification,
  - buffer zones to avoid nutrient leaching,

- increase of habitat heterogeneity, e.g. by:
  - rotational use,
  - conservation of unused areas,

- restoration of grasslands for the expansion of grassland habitats,

- improvement of grassland connectivity,

- conservation measures during the expansion of renewable energies, especially:
  - energy crops: prohibition of grassland conversion,
  - wind power: compliance of minimum distances to habitats of species with conservation concern (especially birds and bats) and temporary turning-off within periods of high bat (or bird) activity,

- monitoring of indicator species vulnerable to climate change,

- floodplain restoration for increasing habitat availability of alluvial grasslands.

For the implementation of these strategies there are special demands concerning the agricultural and power industry sector. Due to the urgent need for improving habitat connectivity and habitat availability there is a great spatial requirement. Therefore, landscape planning must increasingly integrate species conservation aims associated with climate change within landscape plans. Especially, local measures for increasing habitat availability such as the restoration of grasslands are of special importance. As a consequence of improved habitat availability, larger populations of species are promoted and habitat heterogeneity can be increased by a more diverse management. Thereby, the resilience of grassland ecosystems and species to altered environmental conditions is supported (cf. BEHRENS et al. 2009c).

With respect to water management a further drainage and river regulation must be banned for the conservation of alluvial and wet meadows. From a nature conservation viewpoint, stricter legal regulations are necessary for the implementation of species conservation measures in the context of agricultural subsidies. For example, a complete ban of grassland conversion without exceptional rules is necessary (OPPERMANN et al. 2013).

**Further research**

For deriving more species-specific management strategies, it is important to increasingly analyze the effects of climate change on grassland species communities by long-term field and experimental analyses. Thereby, the focus on the following aspects is of special concern:

- effects of different land use regimes on grassland habitats and species under climate change,

- climate change effects on the nutrient cycle and the effects of altered nutrient availability on species,

- cumulative impacts of climate change and existing threats on endangered species,
• determination of regions with high vulnerability to climate change and special demand for action,
• analysis of the efficiency of different measures for improving the adaptability of species to climate change,
• influence of climate change related effects on alluvial and wet ecosystems,
• influence of solar and wind energy plants and biomass crop cultivation on the populations of affected species (especially birds and bats).

3.7 Mires

Direct and indirect effects of climate change

Prolonged drought periods, temperature rise as well as internal eutrophication caused by global warming are the most important climate change effects on species and species communities of bog and fen ecosystems. Even though field studies on the climate change effects on mire ecosystems are still rare, studies demonstrated that climate change (e.g. desiccation, eutrophication, increased atmospheric CO₂-concentrations) alters the competition between typical plant species (BREEUWER et al. 2008, JASSEY et al. 2013). Especially, large water-table fluctuations influence the competition among vascular plants and peat bog mosses whereby changes in species communities are promoted. However, most studies relate to bog ecosystems. Concerning fens knowledge on the impact of climate change is still very poor.

Especially within warm and dry regions of Germany, substantial negative effects of increased drought periods on mire ecosystems are likely (cf. SCHWARZER et al. 2013). Besides regional climate, the effects of climate change are strongly dependent on local site conditions such as the soil water budget or landscape relief (cf. WATTENDORF et al. 2010). Furthermore, the conservation status strongly influences the impact of climate change. Especially within degraded systems such as drained bogs negative effects by climatic changes are likely due to the reduced resilience of these ecosystems to environmental changes. Undisturbed mire ecosystems are more resilient against climatic changes (HÁJKOVÁ et al. 2011). Here, climatic changes effects appear temporally delayed compared to degraded ecosystems.

As a consequence of climate change related habitat changes and the specific habitat demands of mire species, several threatened mire species are regarded as highly vulnerable to climate change and ranges are predicted to decline (e.g. Raised Bog Large Ground Beetle Carabus menetriesi pacholei, Desmoulin’s Whorl Snail Vertigo mouinsiana) (cf. BEHRENS et al. 2009a, KERTH et al. 2014). Especially, increased drying up poses a severe threat to mire species. Concerning bog dragonfly species studies demonstrated that many species are declining due to the increased drying up of the breeding ponds (e.g. Leucorrhinia dubia, Somatochlora arctica, cf. CONZE et al. 2011, OTT 2006, 2010).

Besides direct impacts of climate change there is an increased risk that indirect effects of climate change caused by land use intensification and the expansion of renewable energies affect mire ecosystems due to the high demand for agricultural land. Thereby, the risk increases that habitats are negatively influenced or even destroyed due to land use intensification. Especially, the conversion of grasslands to arable land and the increased installation of wind power plants affect biodiversity within open landscapes. As an example, avoidance reactions to wind power plants were documented for several grassland and mire bird species such as the Golden Plover (Pluvialis apricaria) (PEARCE-HIGGINS et al. 2009).

Action plan and sectoral demands

For conserving mire habitats and threatened mire species vulnerable to climate change it is essential to protect sites from current threats. Especially drainage, land use intensification,
eutrophication and deforestation of mire forests must be prohibited. This is also important from a climate protection point of view for reducing greenhouse gas emissions (DRÖSLER et al. 2011, 2012). Furthermore, the following actions are necessary for the conservation of mire ecosystems and threatened mire species vulnerable to climate change:

- rewetting and restoration of mires for increasing resilience to altered environmental conditions,
- development of site-specific management recommendations within managed sites: implementation of measures increasing habitat heterogeneity (e.g. diversification of management within different parts of the site) for the promotion of local adaptability of species to climatic changes,
- establishment of buffer zones on adjacent agricultural sites to avoid nutrient input,
- improvement of wetland connectivity (cf. REICH et al. 2012),
- specific species conservation measures in the context of the expansion of renewable energies (e.g. respect of essential minimum distances to breeding habitats of threatened bird species during site selection for wind turbines, cf. LAG VSW 2015),
- monitoring of indicator species for long-term analyses on the effects of climate change.

For the conservation of mire ecosystems special demands exist with respect to the agricultural sector. Drainage and land use intensification on adjacent sites must be banned. Instead, rewetting and low-intensive land use must be promoted on agricultural sites surrounding mires for mitigating the risk of nutrient input and increasing habitat size for wetland species. Due to the high demand for agricultural land it is extremely important that adaptations strategies for species conservation are increasingly implemented within landscape plans. With respect to politics increased legal measures are essential for promoting the expansion of renewable energies with respect to environmental interests (e.g. by increased compensation payments in the context of specific conservation measures and more strict regulations of the minimum demands for receiving subsidies in line with the Communal Agricultural Policy, cf. OPPERMANN et al. 2013).

Further research

Due to reduced summer precipitation mire ecosystems are dramatically influenced by climate change. Field observations identified an increased risk of drying up of wet ecosystems and ponds as a severe threat for wetland species. Furthermore, the effects of climate change influence mire vegetation and lead to changes in competition among species. However, long-term field studies are necessary for detecting the cumulative impacts of different climate change related effects on species communities for developing specific management recommendations. Especially with respect to fen ecosystems, knowledge on the influence of climate change on species communities is still poor.

3.8 Heathlands

Direct and indirect effects of climate change

In the course of global warming, changes of typical heathland communities are likely as species react differently to altered climatic conditions (cf. KREYLING et al. 2008, PEÑUELAS et al. 2007). Due to eutrophication by atmospheric nitrogen depositions this effect is amplified as higher nutrient levels favor more competitive species (HÄRDTLE et al. 2013, SOUTHON et al. 2012). Especially within dry regions characterized by low summer precipitation (e.g. southern Brandenburg or Lusatia, cf. PETERMANN et al. 2007) the vulnerability of heathland to climate change is evaluated as high. Within subcontinental regions, heather (Calluna vulgaris) is sensitive to increased drought (cf. SCHELLENBERG & BERGMEIER 2014). Furthermore, land
use intensification poses a severe threat to heathland ecosystems due to the increased demand for agricultural land and increased nutrient inputs.

Even though studies on the climate change effects on wet heathlands are rare, climate change is regarded as a severe threat for this ecosystem (Behrens et al. 2009b). Due to increased summer drought, substantial changes of wet heathlands may result from the invasion of mesophilous species. As a consequence of the expected habitat changes, several threatened heathland species are classified as vulnerable to climate change. This applies especially to hydrophilous species restricted to wet heathland ecosystems such as some carabid beetles (e.g. Carabus nitens, Cymindis vaporariorum, Trichocellus cogantus) or the Moor Frog (Rana arvalis) (cf. Assmann & Janssen 1999, Behrens et al. 2009a, Irmler & Gürlich 2004, KERTH et al. 2014).

**Action plan and sectoral demands**

For the conservation of heathland ecosystems and species, it is essential to promote their resilience to environmental changes. Consequently, current threats must be mitigated by suitable conservation measures. Especially, the reduction of nutrient inputs is of special significance for promoting the adaptability of heathland ecosystems to environmental changes. Therefore, the establishment of buffer zones with low-intensive land use and the abandonment of fertilization on adjacent agricultural sites are especially relevant. For the conservation of wet heathlands and their associated species (e.g. Natterjack Toad Bufo calamita, Moor Frog Rana arvalis) the maintenance of the natural water balance must be guaranteed.

By increasing habitat diversity and differently structured areas within heathlands (e.g. by the application of different management techniques on different sites) the adaptability of species to extreme climatic changes is promoted (Behrens et al. 2009c). This can be achieved by the introduction of temporarily or spatially rotating management and the conservation of temporarily unmanaged areas.

In the long run, it is likely that the significance of shaded or densely growing vegetation structures will become more relevant for the conservation of heathland species sensitive to drought. For example, heather is more productive under shaded conditions within subcontinental regions in Germany (Schellenberg & Bergmeier 2014). Therefore, a differentiated consideration of Calluna-heathlands and redefinition of the Habitats Directive habitat types 2310 and 4030 by differentiating between atlantic and subcontinental varieties is suggested (Schellenberg & Bergmeier 2014). Thus, a more regionalized evaluation and management planning of the habitat type would be possible.

Furthermore, many heathland species are dependent on a network of open habitats for supporting range shifts (cf. Reich et al. 2012). The establishment of a pan-European network of open habitats is of special importance for promoting large-scale range shifts. Additionally, it is highly important to increase heathland availability by restoration measures for stabilizing the populations of threatened heathland species (cf. Borchard et al. 2013). Furthermore, the monitoring of threatened species vulnerable to climate change and key species (e.g. heather) is increasingly important for identifying the specific effects of climate change and deriving adapted conservation measures.

For preventing negative effects by land use intensification and the expansion of renewable energies (e.g. solar or wind energy plants) on heathland biodiversity, the planning of priority sites for the use of renewable energies by considering nature conservation aims is especially important. Thereby, the consideration of minimum distances to sites of high conservation value is of special concern for mitigating negative effects on threatened species.

Due to the increased spatial requirement for the conservation of heathlands under climate change (e.g. the establishment of buffer zones, restoration and the improvement of habitat connectivity) there are special demands concerning agriculture and landscape planning. Na-
ture conservation adaptation strategies must be increasingly integrated within landscape plans. For mitigating threats by eutrophication, low-intensive land use should be implemented on agricultural sites adjacent to heathlands. Additionally, the installation of solar or wind energy plants on sites adjacent to heathlands and within sites functioning as relevant habitats for threatened heathland species should be avoided by landscape planning and power energy. Additionally, all actions causing drainage of wet heathland must be avoided by agriculture and water management.

**Further research**

For developing species-specific conservation strategies further research is necessary to analyze the climate change effects on threatened and relevant key heathland species. Especially field observations are relevant, in order to survey the results of sensitivity analyses and projections of the future distributions of species and to identify species vulnerable to climate change. Thereby, it is especially important to focus on poorly studied species groups such as carabid beetles or cryptogams. Furthermore, studies are necessary, for analyzing the cumulative effects of different climate change related effects on heathland ecosystems and species. As many endangered heathland species are characterized by small populations and restricted ranges, the evaluation of a minimum population size and area is necessary for long-term conservation. Due to the specific regional impact of climate change on heathland ecosystems the identification of regions with special demand for action is of special importance.

**3.9 Forests**

**Direct and indirect effects of climate change**

In the course of climate change temperature rise and changes of water balance will cause alterations of forest tree communities. In contrast to native deciduous tree species, coniferous species are regarded as highly vulnerable to climate change (KÖLLING & ZIMMERMANN 2007). Especially, increased drought stress poses a severe threat to species such as the European Beech (*Fagus sylvatica*). This especially holds true under extreme conditions such as subcontinental climates or on shallow soils (cf. MICHELOT et al. 2012, MILAD et al. 2012, SCHERRER et al. 2011).

Due to increased warming and drying up caused by reduced summer precipitation wet forest ecosystems such as bog or alluvial forests and montane or alpine forest types are regarded as extremely vulnerable to climate change (MÜLLER-KROEHLING et al. 2007). In contrast, it is predicted that southerly distributed forest types will expand northwards and establish in Central Europe in the long run (BITTNER & BEIERKUHNLEIN 2014). Next to warming, extreme climatic events such as heat waves or flooding and storms are regarded as important climate change related effects with impact on forest ecosystems (MILAD et al. 2012, SCHELLHAAS et al. 2010, UNSELD 2013). Furthermore, global warming affects the frequencies of pest outbreaks and the distribution of pathogens. Especially, within monocultures there is an increased risk of pest outbreaks caused by the negative effects of climate change such as increased drought stress (LINDNER et al. 2010).

Besides the direct effects of warming altered vegetation structures and habitat conditions are predicted to influence biodiversity and promote species losses (cf. BRAUNISCH et al. 2014). Extensive species declines are especially expected for threatened wet forest species due to increased drying up of the forests in summer (cf. BEHRENS et al. 2009a).

Furthermore, caused by the prolonged vegetation period and earlier foliation (cf. MENZEL 2003) biotic interactions and food webs are influenced when species react differently to phenological changes (e.g. HEGYI et al. 2013). Therefore, changes within species communities due to shifts in abundance and losses of species are likely.
In addition to the direct effects of climate change, indirect effects of climate change affect forest ecosystems. The increased wood biomass extraction in line with bioenergy use (cf. Höltermann & Röhlig 2012) and the expansion of wind power on forest sites pose severe threats to forest ecosystems. As a consequence of this and essential site development measures for installing wind power plants, the vulnerability of threatened forest species increases (BFN 2011). Furthermore, silvicultural adaptation strategies to climate change such as large-scale forest conversions will have strong impacts on typical forest communities.

**Action plan and sectoral demands**

With respect to habitat conservation under climate change, the adaptive capacity of forest ecosystems to climatic changes must be promoted by suitable silvicultural measures such as the site-specific selection of tree species composition and an appropriate management (Hickler et al. 2012). The conversion of monocultures (e.g. stands of pine or spruce) into near-natural forests adapted to local site conditions is essential and must be promoted. Thereby, synergistic effects for species conservation must be considered by forestal planning (e.g. conservation of dead wood, rewetting of wet forests, cf. Schlumprecht et al. 2014).

One target of the National Biodiversity Strategy and Action Plan is the establishment of naturally developing forests within 5% of the German woodland area (BMU 2007). According to Meyer et al. (2011) these forests should be implemented on forest sites of high conservation value. For the realization of species conservation measures within silviculturally managed forests subsidies must be increasingly promoted for managers of private forests. Thereby, the subsidy programs of the federal states should be increasingly used.

Also with respect to climate protection, the conservation and expansion of forest areas are of special importance due to the important sink function of this ecosystem (von Haaren et al. 2010). However, conservation aims must be respected during afforestation (von Haaren et al. 2010). Especially, within low-intensively used agricultural landscapes which represent important habitats for threatened species of open habitats forestation should be banned.

With regards to species conservation, specific measures must be considered during the implementation of forestal adaptation strategies. Within forests which function as relevant habitats for threatened species the conservation of essential habitat structures (e.g. glades or ponds) must be respected (cf. Milad et al. 2012). Furthermore, the improvement of habitat connectivity is of special relevance for supporting species movements on a (supra)regional level. Especially, within northern and western Germany the forest habitat network must be developed as it is too fragmentary to support large-scale range shifts (Reich et al. 2012). Additionally, there is an increased demand for considering species conservation aims during the expansion of wind energy and woodfuel harvesting on forest sites. Thereby, the following actions are relevant:

- site selection with respect to species conservation aims: respect of sufficient minimum distances to relevant habitats of birds and bats in terms of wind power development (cf. Hurst et al. 2016, LAG VSW 2015),
- temporary turning-off of wind turbines during times of high bird or bat activity (e.g. migration periods, cf. Brinkmann et al. 2011),
- abandonment of intensive silvicultural measures for woodfuel harvesting within sites of special relevance for species conservation,
- implementation of silvicultural measures according to minimum demands of nature and species conservation (cf. Hennenberg & Marggraff 2012, Höltermann & Röhlings 2012).

For the conservation of forest ecosystems and their communities, forestry must increasingly respect the principles of an ecological and sustainable forest management. Due to the inten-
sification of silviculture in line with increased woodfuel harvesting there is a great demand for specifying the principles of an ecological forest management and for regulating these legally (cf. HÖLTERMANN & RÖHLING 2012, WINKEL & VOLZ 2003). Consequently, the demands for an appropriate management must be adapted to climate change (KUNZE et al. 2013). With respect to landscape planning species conservation interests must be implemented within landscape plans, especially in terms of renewable energies. Thereby, the determination of exclusive areas for the conservation of forest ecosystems is of special relevance. For supporting range shifts of species, priority areas must be established for the improvement of woodland connectivity. Concerning the power industry species conservation concerns must be respected throughout the expansion of renewable energies (especially in terms of wind power and wood fuel extraction, e.g. minimum distances to habitats of affected species in the context of wind power).

**Further research**

For understanding the long-term effects of climate change on forest ecosystems, there is urgent need for analyzing the suitability of different silvicultural adaptation strategies (e.g. tree species selection, proveniences of tree species, harvesting measures. cf. KONNERT 2007, KÖLLING et al. 2008) and the adaptive capacity of native tree species to climate change. In addition to that, analyses are necessary for evaluating the impact of forestal adaptation strategies on biodiversity. On the basis of the findings specific conservation recommendations must be defined.

Generally, the knowledge on climate change related effects on woodland communities and threatened woodland species is very poor. Besides long-term effects on tree species, it is extremely important to analyze the short-term effects such as structural changes within the shrub or herb layer or changes of biotic interactions on biodiversity.

Concerning the expansion of renewable energies long-term studies and before and after studies are necessary for analyzing the effects on the populations of affected species. This holds true especially to woodfuel extraction and the expansion of wind power on forest sites. Thereby, the definition of necessary minimum distances to habitats relevant for species conservation is of great significance, especially with respect to bats (cf. BRINKMANN et al. 2011, HURST et al. 2015, VOIGT et al. 2015). Furthermore, adequately knowledge is important to what extent the spatial proximity to summer and winter quarters determine bat activity and collision risk at wind power plants (s. HURST et al. 2016). Standardized methods must be developed for surveying activity and space utilization of bats and birds and for evaluating the collision risk (e.g. HURST et al. 2015, 2016). In general, knowledge on the influence of differently sized wind power plants on the collision risk of birds and bats is still poor.

**3.10 Alpine habitats**

**Direct and indirect effects of climate change**

Alpine habitats are threatened by climate change due to vertical shifts of vegetation zones and the expansion of lowland species caused by higher temperatures. Several studies demonstrate that plant species of lower altitudes are expanding within alpine habitats (e.g. KUDERNATSCH 2007, PAROLO & ROSSI 2008, PAULI et al. 2012). Particularly dwarf shrubs and grass species as well as evergreen species are promoted by increased temperatures (KUDERNATSCH et al. 2008, VENN et al. 2012). Especially for endemic alpine species within summits the extinction risk is increased by warming and the shift of vegetation zones (DIRNBÖCK et al. 2011). However, many alpine plant species seem to be relatively persistent. Therefore, an increase of species richness is typical within alpine habitats (e.g. KUDERNATSCH 2007, VENN et al. 2012). For different animal groups the promotion of thermophilous species due to global warming has also been documented in different alpine regions (PIZZOLOTTO et al. 2013, ROTH et al. 2014).
As a consequence of temperature rise and altered rainfall, extensive declines of cold-adapted and hydrophilous species are expected, especially within lower altitudes (cf. PIZZOLOTTO et al. 2013, WILDERMUTH 2012). In the course of climate change, the extinction risk of alpine habitats is assumed to increase due to the reduced available area caused by the upward shift of habitats and species from lower altitudes. Therefore, threatened alpine species such as the Rock Ptarmigan (*Lagopus muta*) are regarded as highly vulnerable to climate change (cf. PETRAS 2014, REVERMANN et al. 2012). Especially, for species of open habitats a reduced habitat availability is predicted due to the expansion of shrubs and trees to higher altitudes (cf. CHAMBERLAIN et al. 2013). In addition to temperature rise, further climate change related effects such as the prolongation of the vegetation period and reduced snowfall have impact on alpine biodiversity. Especially with respect to fauna complex interactions between different climate change related effects such as phenological changes and shortened snow cover periods are likely to influence alpine biodiversity (cf. NOVOA et al. 2008, REVERMANN et al. 2012).

At present, adaption strategies of the tourism industry affect alpine ecosystems as an indirect effect of climate change and increase the risk of endangerment for alpine ecosystems. Especially, the increased use of artificial snow as a consequence of reduced snowfall poses a severe threat for alpine ecosystems (cf. DE JONG 2011). The application of artificial snow affects alpine ecosystems by the specific chemical and physical characteristics of artificial snow. Furthermore, water abstraction for producing snow causes dewatering of alpine water systems and wetlands with drastic effects on alpine wetland ecosystems (DE JONG 2011, KESSLER et al. 2012, NEWESELY 1999, RIXEN et al. 2003).

**Action plan and sectoral demands**

For the protection of threatened alpine species measures for conserving alpine ecosystems are necessary. Thereby, the abandonment of drainage of wetland ecosystems and the ban of forestation of open habitats with high conservation value are of special significance. Generally, land use intensification should be avoided within the whole of the Alpine region. The implementation of low intensity land use should be promoted within intensively managed sites for increasing habitat availability for threatened species dependent on low land use intensity. Furthermore, measures must be undertaken for mitigating existing threats by increased recreational and touristy use and the construction of infrastructure facilities (e.g. designation of conservation areas, ban of the use of artificial snow and the construction of touristy facilities within sensitive habitats and regions of high importance for the conservation of threatened species vulnerable to climate change). As many threatened species with a high vulnerability to climate change are characterized by small populations, the promotion of population increase is of special importance for long-term conservation (cf. KERTH et al. 2014). Therefore, species-specific conservation measures are necessary. Yet, more detailed research is necessary for comprehending the climate change effects on threatened alpine species and for developing species-specific action plans.

For facilitating the adaptability of species to climate change it is important to increase habitat heterogeneity. Therefore, the conservation and creation of habitats under consideration of long ecological gradients is an important strategy for species conservation under climate change (BEHRENS et al. 2009c). Many alpine species are characterized by a narrow thermal niche and are forced to shift to higher altitudes with ongoing temperature rise. In order to promote upward range shifts the improvement of habitat connectivity on a horizontal and vertical level is of great importance.

The essential strategies for the conservation of alpine species requires special actions by landscape planning and tourism. The expansion of touristy and technical facilities (e.g. hiking routes, ski areas, water storage reservoirs for the production of artificial snow) must be banned within sensitive ecosystems and habitats of special value for species conservation.

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Negative effects caused by tourism must be mitigated by specific measures such as the designation of protected areas and the ban of the application of artificial snow within sensitive areas. Furthermore, there is a high demand for increased public relations for informing tourists about nature conservation issues and for mitigating disturbance within sensitive areas.

The spatial demands must be increasingly respected within landscape plans. Furthermore, areas with high restoration potential must be identified and legally protected. Generally, agricultural and water economic measures leading to dehydration of wetland areas must be avoided.

Further research

Knowledge on the climate change effects on alpine species is still poor. Even though many studies document the long-term development of alpine vegetation, further research is necessary to investigate the direct and indirect effects of climate change on alpine ecosystems and species for the specification of management strategies. Habitat types and species with priority for action (e.g. threatened species vulnerable to climate change which were selected within the study) must be analyzed in more detail. In addition, the efficiency of adaptation strategies must be analyzed with respect to the population development of threatened species. Finally, there is a great demand for investigating the effects of climate change on ecosystem processes and the development of tourism (e.g. increased tourism activity due to the prolongation of the vegetation period) in more detail for the concretion of conservation strategies.

3.11 Buildings

Indirect effects of climate change

As a consequence of increasing energetic insulation of buildings for reducing energy consumption and CO₂ emissions, breeding sites of birds (e.g. Common Swift *Apus apus*, Common House Swift *Delichon urbica*) and bat roosts are destroyed when conservation measures are neglected (Maurer-Wohlratz et al. 2011). By the installation of thermal insulation composite systems at the front of buildings and the redevelopment of attic floors, declines of bat roosts are promoted (Petersen & Krebs 2012). Thereby, relevant openings offering access into attics are often destroyed for attic-inhabiting bat species or climatic conditions change with negative impact on bats. For the conservation of bats and other species, conservation measures must be respected during the energetic insulation of buildings. Several threatened bat species which use buildings as reproduction or wintering habitats are considered as vulnerable to climate change (e.g. Western Barbastelle *Barbastella barbastellus*, Northern Bat *Eptesicus nilssonii*, Common Pipistrelle *Pipistrellus pipistrellus*, Particoloured Bat *Vespertilio murinus*, cf. Behrens et al. 2009a, Jaeschke et al. 2014, KERTH et al. 2014). Therefore, the following action plan focuses on the conservation of bats.

Action plan and sectoral demands

If possible, bat roosts and their entries should be protected from any damage during the restoration works. This is especially important when adjacent roosts are absent and there is no possibility for installing substitute roosts. Furthermore, the conservation of roosts is especially relevant when species are present which typically avoid bat boxes for roosting (e.g. Western Barbastelle, Particoloured Bat). Especially the location of the roost entries plays an important role for the conservation of bats at buildings. If possible, these must be conserved for increasing the likelihood of a resettlement of the roosts after the insulation measures are finished.

Before the restoration is carried out, it is essential to analyze which species inhabit the building and which parts of the building function as breeding or roosting sites (cf. Reiter & Zahn 2005). Restoration must be undertaken when the bats are absent from the building. If it is not feasible to conserve roosts during restoration, substitute roosts must be established. There-
fore, several technical solutions are available (cf. MAURER-WOHLATZ et al. 2011, PETERSEN & KREBS 2012, SCHMIDT 2014). Ideally, substitutional roosts should be developed according to the conditions of the former roosts. Even when traditional roosts are conserved, it is recommended to establish new roosts within different parts of the building and different aspects for increasing the diversity of differently structured and tempered roosts (MAURER-WOHLATZ et al. 2011, REITER & ZAHN 2005). Thereby, local adaptability of bats to different temperature conditions is supported. With respect to climate change this is of special importance as extreme climatic weather events such as heat waves are predicted to occur more frequent.

For the implementation of the essential conservation measures there are special demands concerning the responsible bodies initiating the insulation measures (e.g. the owner of the building) and the architects and craftsmen which often detect bat roosts during restoration. These bodies are legally obligated to respect species conservation aims according to § 44 et seqq. of the Federal Nature Conservation Act before and during the construction works. For determining whether a species conservation assessment is necessary it is recommended to contact the local nature conservation agency or consult an approved assessor prior to restoration. Generally, craftsmen must be increasingly informed about the significance of buildings as habitats for species and the legal situation.

In the context of extensive financial promotion of thermal insulation (cf. BMWI 2015) there is high demand that species conservation aims are systematically and bindingly respected and integrated within sponsorships. By means of promoting species conservation actions habitat quality and quantity is increased for threatened bat species which has positive effects on their populations.

**Further research**

For gaining knowledge on species conservation measures in line with thermal insulation of buildings it is essential to evaluate current knowledge on this issue. Thereby, it is especially important to consider unpublished studies such as species conservation surveys. Furthermore, increased analyses on the success of conservation measures must be carried out by before and after studies for the specification of conservation measures. In addition to that, the analysis of the following aspects is of special significance for the conservation of bat species with respect to climate change and increased thermal insulation:

- How are bat species dependent on buildings affected by thermal insulation and how can the loss of quarters be compensated?
- How can bat species be scared off during construction phase without being harmed?
- How are habitat selection and overwintering of bats influenced by climate change?
4 Conclusions

Action plan for species conservation under climate change

The main target of nature protection is the conservation of biodiversity (BMU 2007). However, due to the severe environmental impact of global warming changes of species communities will be inevitable and must be accepted by nature conservation (KUNZE et al. 2013, IBISCH & KREFT 2008, WILKE et al. 2011).

Many highly threatened species vulnerable to climate change are characterized by a certain adaptive capacity to environmental changes (KERTH et al. 2014). In times of climate change, today’s conservation must achieve that this capacity is supported by specific conservation strategies (KERTH et al. 2014). Therefore, the improvement of habitat connectivity, the increase of habitat heterogeneity and the restoration of habitats (e.g. rivers, mires, wet grassland) are relevant strategies. By means of these strategies the resilience of ecosystems to environmental changes and population recoveries of species are promoted. However, with respect to highly threatened species species-specific measures become increasingly important for conservation. This holds especially true for species threatened by the indirect effects of climate change such as the expansion of renewable energies. Therefore, the implementation and adaptation of species-specific conservation programs to climate change are of special relevance. Also with respect to species characterized by small ranges or a high extinction risk such as alpine species, the implementation of species-specific conservation programs is important for preventing extinction caused by climate change. Thereby, it is important to gain further knowledge on how these species are specifically affected by climate change. Besides endangered species, the effects of climate change must be increasingly documented for relevant key species such as Calluna vulgaris or Zostera marina for identifying the climate change effects on the ecosystem level.

However, today’s species conservation must respect expanding species which profit from climate change. Even though the conservation of biodiversity is the main target of species conservation, conservationists must be aware of the increasing challenge for preserving the current state of species communities under climate change. Alterations of communities due to the extinction of species and expansion of new species are inevitable and must be accepted by conservation. A prioritization of species conservation aims is therefore of increasing relevance. A more detailed analysis of the expenditures for the costs and staff in line with species conservation measures and management is of special significance for the evaluation of relevant measures (KREFT et al. 2013).

Further research

At present, knowledge on the climate change effects on endangered species is still poor, so that in most cases it is not yet possible to derive species-specific management strategies. Especially, the interacting impact of different climate change effects on species is still poorly understood. As an example, many dragonfly species profit from warming and the prolongation of the vegetation period. However, the drying up of ponds increases due to prolonged drought events (cf. OTT 2012). Next to physical influences and habitat changes biotic interactions are influenced by climate change related effects such as range alterations and promotion of thermophilic native or alien species (KLEINBAUER et al. 2010, NEHRING 2016) or different reactions of species to phenological changes. The effect of phenological changes on species communities is still unknown in Germany (UBA 2015).

Due to the complex impact of climate change on biodiversity, predictions of climate change effects on species are uncertain. For analyzing the effects of climate change on species communities more long-term studies and field observations as well as experimental studies are necessary. Therefore, the selection of appropriate indicator species is of special relevance. Additionally, knowledge on the effects of extreme weather effects is still poor.
Finally, it is of special importance to investigate the effects of climate change related habitat changes on species. This especially holds true for water dependent or aquatic habitats, for which extreme habitat changes are predicted due to the increase of drought periods.

Furthermore, the efficiency of adaptation measures must be analyzed with respect to threatened species. The increase of local habitat heterogeneity is regarded as an important measure for promoting the adaptability of species (cf. BEHRENS et al. 2009c, FARTMANN et al. 2012). However, there is urgent need for research on how this strategy can be implemented within certain habitat types and how this measure affects species populations.

Dependent on the development of climate change and regional conditions it is expected that climate change effects on species differ greatly. A regional prioritization of adaptation strategies by the identification of regions with special demand for action is therefore of special significance and could be developed subsequently to this action plan.

Concerning the expansion of renewable energies there is special demand for analyzing the effects of renewable energies (especially wind power) on the population development of affected species. Furthermore, increased before and after studies are necessary for analyzing the efficiency of conservation measures and for specifying certain measures. Due to the increased installation of wind power plants within woodlands the effects on affected woodland species and species communities must be analyzed in more detail. In addition to that, more knowledge on the influence of land use changes (especially by the increased cultivation of novel crops) on farmland biodiversity must be gained by field studies. This holds especially true for species groups (e.g. bats, birds, insects) with deficient knowledge on the effects of land use change.

Eine hohe Habitatheterogenität, hier dargestellt am Beispiel einer Tieflandsheide, verringert das Aussterberisiko von Arten.

High local habitat heterogeneity, in this example illustrated for a lowland heathland, decreases the extinction risk of species.

(Foto / Photo: Thomas Fartmann)
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